Freeform Search

Database: US Patents Full-Text Database
US Pre-Grant Publication Full-Text Database
JPO Abstracts Database
EPO Abstracts Database
Derwent World Patents Index
IBM Technical Disclosure Bulletins

Term: L45 and (oscillat$5 or synthesiz$4 or generat$4 or produc$6 or envelop$4 or modulat$5 or waveform$6 or wave-form$6 or shap$5)

Display: 100 **Documents in Display Format:** - **Starting with Number** 1

Generate: ○ **Hit List** ◉ **Hit Count** ○ **Side by Side** ○ **Image**

Search | Clear | Help | Logout | Interrupt

Main Menu | Show S Numbers | Edit S Numbers | Preferences | Cases

Search History

DATE: Monday, September 16, 2002 Printable Copy Create Case

Set Name side by side	Query	Hit Count	Set Name result set
DB=USPT,PGPB,JPAB,EPAB,DWPI,TDBD; PLUR=YES; OP=ADJ			
L46	L45 and (oscillat$5 or synthesiz$4 or generat$4 or produc$6 or envelop$4 or modulat$5 or waveform$6 or wave-form$6 or shap$5)	8	L46
L45	L44 and (control$5 or custom$9 or interact$6 or interfac$4 or inter-fac$4 or inter-act$6 or user or operator or technician or console)	8	L45
L44	L42 and (phase)	8	L44
L43	L42 and (gradient)	0	L43
L42	L41 and (radio-frequency or rf or "radio frequency")	8	L42
L41	L40 and (keyboard or mouse or window$4 or default or value or scan$5 or disk or stor$4)	8	L41
L40	L39 and (analog or digital$3 or ADC or dac or "analog-to-digital" or "digital-to-analog")	8	L40

L39	L38 and (channel or receiv$4 or transmit$6 or detect$5 or coil)	8	L39
L38	L37 and (real or timing or deliver$4)	8	L38
L37	L36 and (scaler or scaling or scale or time or block or line or vertical$3)	8	L37
L36	L35 and (display$4 with pulse with sequence)	8	L36
L35	L15 and ((editor or editing or edit or tailor$4) with menu)	9	L35
L34	L12 and (display$4 with pulse with sequence)	1	L34
L33	L26 and (display$4 with pulse with sequence)	8	L33
L32	L29 and (display$4 with pulse with sequence)	0	L32
L31	L30 and (display$4 with pulse with sequence)	0	L31
L30	L29 and (real or timing or deliver$4)	1	L30
L29	L28 and (scaler or scaling or scale or time or block or line or vertical$3)	2	L29
L28	L27 and (channel or receiv$4 or transmit$6 or detect$5 or coil)	2	L28
L27	L26 and (gradient)	2	L27
L26	L25 and (radio-frequency or rf or "radio frequency")	11	L26
L25	L24 and (phase)	16	L25
L24	L20 and (keyboard or mouse or window$4 or default or value or scan$5 or disk or stor$4)	17	L24
L23	L22 and (phase)	2	L23
L22	L21 and (gradient)	2	L22
L21	L20 and (radio-frequency or rf or "radio frequency")	11	L21
L20	L19 and (analog or digital$3 or ADC or dac or "analog-to-digital" or "digital-to-analog")	17	L20
L19	L18 and (oscillat$5 or synthesiz$4 or generat$4 or produc$6 or envelop$4 or modulat$5 or waveform$6 or wave-form$6 or shap$5)	17	L19
L18	L17 and (control$5 or custom$9 or interact$6 or interfac$4 or inter-fac$4 or inter-act$6 or user or operator or technician or console)	17	L18
L17	L16 and ((editor or editing or edit or tailor$4) with (pulse or choice or selection or menu or sequence or shape or waveform$6 or wave-form$6 or "wave form$6" or envelop$5 or signal or echo))	17	L17
L16	L15 and (editor or editing or edit or tailor$4)	33	L16
L15	L14 and (menu)	77	L15
L14	L13 and (display$4 or monitor$4 or computer or processer or processor or gui or crt or graphical$4 or console)	4119	L14
L13	L1 and (pulse with (sequence or sequencer or control$4 or custom$9 or programmer or programer))	6213	L13
L12	L11 and (gradient)	7	L12
L11	L10 and (radio-frequency or rf or "radio frequency")	16	L11

L10	L8 and (analog or digital$3 or ADC or dac or "analog-to-digital" or "digital-to-analog")	33	L10
L9	L8 and (analod or digital$3 or ADC or dac or "analog-to-digital" or "digital-to-analog")	33	L9
L8	L7 and (oscillat$5 or synthesiz$4 or generat$4 or produc$6 or envelop$4 or modulat$5 or waveform$6 or wave-form$6 or shap$5)	33	L8
L7	L6 and (keyboard or mouse or window$4 or default or value or scan$5 or disk or stor$4)	33	L7
L6	L5 and (control$5 or custom$9 or interact$6 or interfac$4 or inter-fac$4 or inter-act$6 or user or operator or technician)	33	L6
L5	L4 and (menu)	33	L5
L4	L3 and (display$4 or monitor$4 or computer or processer or processor or gui or crt or graphical$4)	451	L4
L3	L2 and (editor or editing or edit or tailor$4)	523	L3
L2	L1 and (pulse with (sequence or sequencer or control$4 or custom$9))	6184	L2
L1	((magnetic adj resonance) or MRI or NMR)	132862	L1

END OF SEARCH HISTORY

Search Results - Record(s) 1 through 16 of 16 returned.

☐ 1. Document ID: US 20020115941 A1

L11: Entry 1 of 16 File: PGPB Aug 22, 2002

PGPUB-DOCUMENT-NUMBER: 20020115941
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020115941 A1

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in interior body regions

PUBLICATION-DATE: August 22, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Whayne, James G.	Saratoga	CA	US	
Swanson, David K.	Mountain View	CA	US	
Panescu, Dorin	Sunnyvale	CA	US	
Dupree, Daniel A.	Saratoga	CA	US	

US-CL-CURRENT: 600/523; 600/374, 702/68, 707/102

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

☐ 2. Document ID: US 20020103429 A1

L11: Entry 2 of 16 File: PGPB Aug 1, 2002

PGPUB-DOCUMENT-NUMBER: 20020103429
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020103429 A1

TITLE: Methods for physiological monitoring, training, exercise and regulation

PUBLICATION-DATE: August 1, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
deCharms, R. Christopher	Moss Beach	CA	US	

US-CL-CURRENT: 600/410

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

☐ 3. Document ID: US 20020103428 A1

L11: Entry 3 of 16 File: PGPB Aug 1, 2002

PGPUB-DOCUMENT-NUMBER: 20020103428
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020103428 A1

TITLE: Methods for physiological monitoring, training, exercise and regulation

PUBLICATION-DATE: August 1, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
deCharms, R. Christopher	Moss Beach	CA	US	

US-CL-CURRENT: 600/410

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 4. Document ID: US 20010044585 A1

L11: Entry 4 of 16 File: PGPB Nov 22, 2001

PGPUB-DOCUMENT-NUMBER: 20010044585
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20010044585 A1

TITLE: Interactive systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions

PUBLICATION-DATE: November 22, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Dupree, Daniel A.	Saratoga	CA	US	
Nguyen, Tuan	Austin	TX	US	
Panescu, Dorin	San Jose	CA	US	
Whayne, James G.	San Jose	CA	US	
McGee, David	Sunnyvale	CA	US	
Swanson, David K.	Campbell	CA	US	

US-CL-CURRENT: 600/509

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 5. Document ID: US 6389311 B1

L11: Entry 5 of 16 File: USPT May 14, 2002

US-PAT-NO: 6389311
DOCUMENT-IDENTIFIER: US 6389311 B1

TITLE: Systems and methods using annotated images for controlling the use of

diagnostic or therapeutic instruments in interior body regions

DATE-ISSUED: May 14, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Whayne; James G.	Saratoga	CA		
Swanson; David K.	Mountain View	CA		
Panescu; Dorin	Sunnyvale	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

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☐ 6. Document ID: US 6289239 B1

L11: Entry 6 of 16 File: USPT Sep 11, 2001

US-PAT-NO: 6289239
DOCUMENT-IDENTIFIER: US 6289239 B1

TITLE: Interactive systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions

DATE-ISSUED: September 11, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Panescu; Dorin	Sunnyvale	CA		
McGee; David	Sunnyvale	CA		
Whayne; James G.	Saratoga	CA		
Burnside; Robert R.	Mountain View	CA		
Swanson; David K.	Mountain View	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

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☐ 7. Document ID: US 6272479 B1

L11: Entry 7 of 16 File: USPT Aug 7, 2001

US-PAT-NO: 6272479
DOCUMENT-IDENTIFIER: US 6272479 B1

TITLE: Method of evolving classifier programs for signal processing and control

DATE-ISSUED: August 7, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Farry; Kristin Ann	Houston	TX	77546	
Fernandez; Julio Jaime	Suger Land	TX	77479	
Graham; Jeffrey Scott	Houston	TX	77064	

US-CL-CURRENT: 706/13; 700/213, 700/250, 706/14

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 8. Document ID: US 6192266 B1

L11: Entry 8 of 16 File: USPT Feb 20, 2001

US-PAT-NO: 6192266
DOCUMENT-IDENTIFIER: US 6192266 B1

TITLE: Systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions using real and idealized images

DATE-ISSUED: February 20, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Dupree; Daniel A.	Saratoga	CA		
Nguyen; Tuan	San Jose	CA		
Panescu; Dorin	Sunnyvale	CA		
Whayne; James G.	Saratoga	CA		

US-CL-CURRENT: 600/427; 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 9. Document ID: US 6115626 A

L11: Entry 9 of 16 File: USPT Sep 5, 2000

US-PAT-NO: 6115626
DOCUMENT-IDENTIFIER: US 6115626 A

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in instruments in interior body regions

DATE-ISSUED: September 5, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Whayne; James G.	Saratoga	CA		
Swanson; David K.	Mountain View	CA		
Panescu; Dorin	Sunnyvale	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/427; 600/523

☐ 10. Document ID: US 6106460 A

L11: Entry 10 of 16 File: USPT Aug 22, 2000

US-PAT-NO: 6106460
DOCUMENT-IDENTIFIER: US 6106460 A

TITLE: Interface for controlling the display of images of diagnostic or therapeutic instruments in interior body regions and related data

DATE-ISSUED: August 22, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Panescu; Dorin	Sunnyvale	CA		
McGee; David	Sunnyvale	CA		
Whayne; James G.	Saratoga	CA		
Burnside; Robert R.	Mountain View	CA		
Swanson; David K.	Mountain View	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/300

☐ 11. Document ID: US 6014581 A

L11: Entry 11 of 16 File: USPT Jan 11, 2000

US-PAT-NO: 6014581
DOCUMENT-IDENTIFIER: US 6014581 A

TITLE: Interface for performing a diagnostic or therapeutic procedure on heart tissue with an electrode structure

DATE-ISSUED: January 11, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Whayne; James G.	Saratoga	CA		
Panescu; Dorin	Sunnyvale	CA		
McGee; David	Sunnyvale	CA		
Dupree; Daniel A.	Saratoga	CA		
Swanson; David K.	Mountain View	CA		
Nguyen; Tuan	San Jose	CA		

US-CL-CURRENT: 600/523

☐ 12. Document ID: US 5465361 A

L11: Entry 12 of 16 File: USPT Nov 7, 1995

US-PAT-NO: 5465361
DOCUMENT-IDENTIFIER: US 5465361 A

TITLE: Microcode linker/loader that generates microcode sequences for MRI sequencer by modifying previously generated microcode sequences

DATE-ISSUED: November 7, 1995

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hoenninger, III; John C.	Oakland	CA		

US-CL-CURRENT: 717/168; 324/309, 324/312

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

☐ 13. Document ID: US 5349294 A

L11: Entry 13 of 16 File: USPT Sep 20, 1994

US-PAT-NO: 5349294
DOCUMENT-IDENTIFIER: US 5349294 A

TITLE: Two and three-dimensionally selective RF pulses for magnetic resonance imaging

DATE-ISSUED: September 20, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Kasuboski; Larry	Solon	OH		

US-CL-CURRENT: 324/309

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

☐ 14. Document ID: US 5304214 A

L11: Entry 14 of 16 File: USPT Apr 19, 1994

US-PAT-NO: 5304214
DOCUMENT-IDENTIFIER: US 5304214 A

TITLE: Transurethral ablation catheter

DATE-ISSUED: April 19, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
DeFord; John A.	Lafayette	IN		
Ely; Joseph F.	West Lafayette	IN		
Fearnot; Neal E.	West Lafayette	IN		

US-CL-CURRENT: 607/105; 604/916, 607/113

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 15. Document ID: US 5144242 A

L11: Entry 15 of 16 File: USPT Sep 1, 1992

US-PAT-NO: 5144242
DOCUMENT-IDENTIFIER: US 5144242 A

TITLE: Continually loadable microcode store for MRI control sequencers

DATE-ISSUED: September 1, 1992

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Zeilenga; Jack H.	San Francisco	CA		
Hoenninger, III; John	Oakland	CA		

US-CL-CURRENT: 324/312; 712/248

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 16. Document ID: US 5041789 A

L11: Entry 16 of 16 File: USPT Aug 20, 1991

US-PAT-NO: 5041789
DOCUMENT-IDENTIFIER: US 5041789 A

TITLE: Magnetic-resonance instrument employing barcode experiment specification

DATE-ISSUED: August 20, 1991

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Keller; Tony	Reinstetten-Forchheim			DE
Laukien; Gunther R.	Rheinstetten			DE
Spraul; Manfred	Ettlingen			DE

US-CL-CURRENT: 324/318; 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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Generate Collection | Print

Term	Documents
RADIO-FREQUENCY.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	12730
RADIO-FREQUENCIES.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	126
RADIO-FREQUENCYS	0
RF.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	156673
RFS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	807
"RADIO FREQUENCY".DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	0
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(L10 AND (RADIO-FREQUENCY OR RF OR "RADIO FREQUENCY")).USPT,PGPB,JPAB,EPAB,DWPI,TDBD.	16

Display Format: - Change Format

Previous Page Next Page

Search Results - Record(s) 1 through 7 of 7 returned.

☐ 1. Document ID: US 20020103429 A1

L12: Entry 1 of 7 File: PGPB Aug 1, 2002

PGPUB-DOCUMENT-NUMBER: 20020103429
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020103429 A1

TITLE: Methods for physiological monitoring, training, exercise and regulation

PUBLICATION-DATE: August 1, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
deCharms, R. Christopher	Moss Beach	CA	US	

US-CL-CURRENT: 600/410

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

☐ 2. Document ID: US 20020103428 A1

L12: Entry 2 of 7 File: PGPB Aug 1, 2002

PGPUB-DOCUMENT-NUMBER: 20020103428
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020103428 A1

TITLE: Methods for physiological monitoring, training, exercise and regulation

PUBLICATION-DATE: August 1, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
deCharms, R. Christopher	Moss Beach	CA	US	

US-CL-CURRENT: 600/410

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

☐ 3. Document ID: US 5465361 A

L12: Entry 3 of 7 File: USPT Nov 7, 1995

US-PAT-NO: 5465361

DOCUMENT-IDENTIFIER: US 5465361 A

TITLE: Microcode linker/loader that generates microcode sequences for MRI sequencer by modifying previously generated microcode sequences

DATE-ISSUED: November 7, 1995

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hoenninger, III; John C.	Oakland	CA		

US-CL-CURRENT: 717/168; 324/309, 324/312

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw. Desc | Image

☐ 4. Document ID: US 5349294 A

L12: Entry 4 of 7 File: USPT Sep 20, 1994

US-PAT-NO: 5349294
DOCUMENT-IDENTIFIER: US 5349294 A

TITLE: Two and three-dimensionally selective RF pulses for magnetic resonance imaging

DATE-ISSUED: September 20, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Kasuboski; Larry	Solon	OH		

US-CL-CURRENT: 324/309

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw. Desc | Image

☐ 5. Document ID: US 5304214 A

L12: Entry 5 of 7 File: USPT Apr 19, 1994

US-PAT-NO: 5304214
DOCUMENT-IDENTIFIER: US 5304214 A

TITLE: Transurethral ablation catheter

DATE-ISSUED: April 19, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
DeFord; John A.	Lafayette	IN		
Ely; Joseph F.	West Lafayette	IN		
Fearnot; Neal E.	West Lafayette	IN		

US-CL-CURRENT: 607/105; 604/916, 607/113

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 6. Document ID: US 5144242 A

L12: Entry 6 of 7 File: USPT Sep 1, 1992

US-PAT-NO: 5144242
DOCUMENT-IDENTIFIER: US 5144242 A

TITLE: Continually loadable microcode store for MRI control sequencers

DATE-ISSUED: September 1, 1992

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Zeilenga; Jack H.	San Francisco	CA		
Hoenninger, III; John	Oakland	CA		

US-CL-CURRENT: 324/312; 712/248

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 7. Document ID: US 5041789 A

L12: Entry 7 of 7 File: USPT Aug 20, 1991

US-PAT-NO: 5041789
DOCUMENT-IDENTIFIER: US 5041789 A

TITLE: Magnetic-resonance instrument employing barcode experiment specification

DATE-ISSUED: August 20, 1991

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Keller; Tony	Reinstetten-Forchheim			DE
Laukien; Gunther R.	Rheinstetten			DE
Spraul; Manfred	Ettlingen			DE

US-CL-CURRENT: 324/318; 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

Generate Collection | Print

Term	Documents
GRADIENT.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	172644
GRADIENTS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	40913
(11 AND GRADIENT).USPT,PGPB,JPAB,EPAB,DWPI,TDBD.	7
(L11 AND (GRADIENT)).USPT,PGPB,JPAB,EPAB,DWPI,TDBD.	7

Display Format: - Change Format

Previous Page Next Page

Search Results - Record(s) 1 through 11 of 11 returned.

☐ 1. Document ID: US 20020115941 A1

L26: Entry 1 of 11 File: PGPB Aug 22, 2002

PGPUB-DOCUMENT-NUMBER: 20020115941
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020115941 A1

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in interior body regions

PUBLICATION-DATE: August 22, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Whayne, James G.	Saratoga	CA	US	
Swanson, David K.	Mountain View	CA	US	
Panescu, Dorin	Sunnyvale	CA	US	
Dupree, Daniel A.	Saratoga	CA	US	

US-CL-CURRENT: 600/523; 600/374, 702/68, 707/102

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

☐ 2. Document ID: US 20010044585 A1

L26: Entry 2 of 11 File: PGPB Nov 22, 2001

PGPUB-DOCUMENT-NUMBER: 20010044585
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20010044585 A1

TITLE: Interactive systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions

PUBLICATION-DATE: November 22, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Dupree, Daniel A.	Saratoga	CA	US	
Nguyen, Tuan	Austin	TX	US	
Panescu, Dorin	San Jose	CA	US	
Whayne, James G.	San Jose	CA	US	
McGee, David	Sunnyvale	CA	US	
Swanson, David K.	Campbell	CA	US	

US-CL-CURRENT: 600/509

☐ 3. Document ID: US 6389311 B1

L26: Entry 3 of 11 File: USPT May 14, 2002

US-PAT-NO: 6389311
DOCUMENT-IDENTIFIER: US 6389311 B1

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in interior body regions

DATE-ISSUED: May 14, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Whayne; James G.	Saratoga	CA		
Swanson; David K.	Mountain View	CA		
Panescu; Dorin	Sunnyvale	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/523

☐ 4. Document ID: US 6289239 B1

L26: Entry 4 of 11 File: USPT Sep 11, 2001

US-PAT-NO: 6289239
DOCUMENT-IDENTIFIER: US 6289239 B1

TITLE: Interactive systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions

DATE-ISSUED: September 11, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Panescu; Dorin	Sunnyvale	CA		
McGee; David	Sunnyvale	CA		
Whayne; James G.	Saratoga	CA		
Burnside; Robert R.	Mountain View	CA		
Swanson; David K.	Mountain View	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/523

☐ 5. Document ID: US 6272479 B1

L26: Entry 5 of 11 File: USPT Aug 7, 2001

US-PAT-NO: 6272479
DOCUMENT-IDENTIFIER: US 6272479 B1

TITLE: Method of evolving classifier programs for signal processing and control

DATE-ISSUED: August 7, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Farry; Kristin Ann	Houston	TX	77546	
Fernandez; Julio Jaime	Suger Land	TX	77479	
Graham; Jeffrey Scott	Houston	TX	77064	

US-CL-CURRENT: 706/13; 700/213, 700/250, 706/14

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 6. Document ID: US 6192266 B1

L26: Entry 6 of 11 File: USPT Feb 20, 2001

US-PAT-NO: 6192266
DOCUMENT-IDENTIFIER: US 6192266 B1

TITLE: Systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions using real and idealized images

DATE-ISSUED: February 20, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Dupree; Daniel A.	Saratoga	CA		
Nguyen; Tuan	San Jose	CA		
Panescu; Dorin	Sunnyvale	CA		
Whayne; James G.	Saratoga	CA		

US-CL-CURRENT: 600/427; 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 7. Document ID: US 6115626 A

L26: Entry 7 of 11 File: USPT Sep 5, 2000

US-PAT-NO: 6115626
DOCUMENT-IDENTIFIER: US 6115626 A

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in instruments in interior body regions

DATE-ISSUED: September 5, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Whayne; James G.	Saratoga	CA		
Swanson; David K.	Mountain View	CA		
Panescu; Dorin	Sunnyvale	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/427; 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 8. Document ID: US 6106460 A

L26: Entry 8 of 11 File: USPT Aug 22, 2000

US-PAT-NO: 6106460
DOCUMENT-IDENTIFIER: US 6106460 A

TITLE: Interface for controlling the display of images of diagnostic or therapeutic instruments in interior body regions and related data

DATE-ISSUED: August 22, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Panescu; Dorin	Sunnyvale	CA		
McGee; David	Sunnyvale	CA		
Whayne; James G.	Saratoga	CA		
Burnside; Robert R.	Mountain View	CA		
Swanson; David K.	Mountain View	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/300

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 9. Document ID: US 6014581 A

L26: Entry 9 of 11 File: USPT Jan 11, 2000

US-PAT-NO: 6014581
DOCUMENT-IDENTIFIER: US 6014581 A

TITLE: Interface for performing a diagnostic or therapeutic procedure on heart tissue with an electrode structure

DATE-ISSUED: January 11, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Whayne; James G.	Saratoga	CA		
Panescu; Dorin	Sunnyvale	CA		
McGee; David	Sunnyvale	CA		
Dupree; Daniel A.	Saratoga	CA		
Swanson; David K.	Mountain View	CA		
Nguyen; Tuan	San Jose	CA		

US-CL-CURRENT: 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 10. Document ID: US 5349294 A

L26: Entry 10 of 11 File: USPT Sep 20, 1994

US-PAT-NO: 5349294
DOCUMENT-IDENTIFIER: US 5349294 A

TITLE: Two and three-dimensionally selective RF pulses for magnetic resonance imaging

DATE-ISSUED: September 20, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Kasuboski; Larry	Solon	OH		

US-CL-CURRENT: 324/309

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 11. Document ID: US 5041789 A

L26: Entry 11 of 11 File: USPT Aug 20, 1991

US-PAT-NO: 5041789
DOCUMENT-IDENTIFIER: US 5041789 A

TITLE: Magnetic-resonance instrument employing barcode experiment specification

DATE-ISSUED: August 20, 1991

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Keller; Tony	Reinstetten-Forchheim			DE
Laukien; Gunther R.	Rheinstetten			DE
Spraul; Manfred	Ettlingen			DE

US-CL-CURRENT: 324/318; 324/322

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Term	Documents
RADIO-FREQUENCY.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	12730
RADIO-FREQUENCIES.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	126
RADIO-FREQUENCYS	0
RF.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	156673
RFS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	807
"RADIO FREQUENCY".DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	0
(25 AND (RADIO-FREQUENCY OR RF OR "RADIO FREQUENCY")).USPT,PGPB,JPAB,EPAB,DWPI,TDBD.	11
(L25 AND (RADIO-FREQUENCY OR RF OR "RADIO FREQUENCY")).USPT,PGPB,JPAB,EPAB,DWPI,TDBD.	11

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Previous Page Next Page

Search Results - Record(s) 1 through 2 of 2 returned.

☐ 1. Document ID: US 5349294 A

L28: Entry 1 of 2 File: USPT Sep 20, 1994

US-PAT-NO: 5349294
DOCUMENT-IDENTIFIER: US 5349294 A

TITLE: Two and three-dimensionally selective RF pulses for magnetic resonance imaging

DATE-ISSUED: September 20, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Kasuboski; Larry	Solon	OH		

US-CL-CURRENT: 324/309

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. Desc | Image

☐ 2. Document ID: US 5041789 A

L28: Entry 2 of 2 File: USPT Aug 20, 1991

US-PAT-NO: 5041789
DOCUMENT-IDENTIFIER: US 5041789 A

TITLE: Magnetic-resonance instrument employing barcode experiment specification

DATE-ISSUED: August 20, 1991

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Keller; Tony	Reinstetten-Forchheim			DE
Laukien; Gunther R.	Rheinstetten			DE
Spraul; Manfred	Ettlingen			DE

US-CL-CURRENT: 324/318; 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

Term	Documents
CHANNEL.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	979824
CHANNELS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	476282
COIL.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	705804
COILS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	224063
RECEIV$4	0
RECEIV.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	719
RECEIVA.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	2
RECEIVABE.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	3
RECEIVABLE.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	34490
RECEIVABLY.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	1081
RECEIVAD.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	1
(L27 AND (CHANNEL OR RECEIV$4 OR TRANSMIT$6 OR DETECT$5 OR COIL)).USPT,PGPB,JPAB,EPAB,DWPI,TDBD.	2

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DOCUMENT-IDENTIFIER: US 5349294 A
TITLE: Two and three-dimensionally selective RF pulses for magnetic resonance imaging

Abstract Text (1):
A sequence controller (30) controls gradient pulse amplifiers (20) and a digital transmitter (24) to apply a conventional magnetic resonance imaging or spectroscopy sequence. One or more of the resonance excitation pulses includes a series of very small tip angle RF pulses (52, 70) applied in rapid succession substantially within the time interval of a normal RF excitation pulse (e.g. 10 msec.). A series of gradient pulses (58x, 58y, 72y, 72z) with linearly diminishing amplitudes and a repetition cycle that is an integer multiple of the duration of the very small tip angle RF pulses are applied such that an excitation trajectory in k-space follows a piecewise linear square spiral (FIG. 3) when gradients are applied along two axes or an octahedral spiral (FIG. 6) when a series of gradient pulses are applied along three axes. The subregion of resonance excitation is selectively shifted along one of the axes by applying a series of frequency offset pulses (66, 76) along one or more of the axes. In this manner, the position of the subregion of resonance excitation is shifted without changing the phase component of the RF pulses.

Brief Summary Text (2):
The present invention relates to the magnetic resonance imaging and spectroscopy arts. It finds particular application in conjunction with dark blood flow tagging for angiographic imaging and will be described with particular reference thereto. However, it should be appreciated that the invention will also find application in connection with magnetic resonance excitation for other magnetic resonance applications.

Brief Summary Text (3):
It is well-known in the magnetic resonance arts that resonance can be excited in a planar region or slice by the simultaneous application of a selective RF pulse and static magnetic field gradient. This selective RF/static magnetic field gradient has been used to create localized excitation in a slice or planar region. This combination of selective RF pulse and static magnetic field gradient has been used in angiographic imaging for flow tagging. Typically, magnetic resonance was excited or saturated in a slice or slices adjacent a planar region or slice of interest. A series of RF pulses applied with a series of static gradients have been used to excite resonance or saturate blood in a plurality of slices or regions around the region of interest.

Brief Summary Text (4):
When a conventional imaging sequence was performed on the slice or other region of interest, the non-blood tissue was imaged normally. However, the blood which was tagged by prior excitation or saturation had different magnetic resonance imaging properties than blood which was not previously excited or saturated. As the blood from the adjacent slice(s) flows into the slice or region of interest, it changes the properties of the blood tissue displayed in the resultant image. This enables the resultant diagnostic images to be used to measure flow, measure flow rate, track flow paths, and the like.

Brief Summary Text (6):
One technique for limiting the tagging region used a series of RF pulses with a series of different static magnetic field gradients to create the desired two-dimensional excitation profile. See for example, "Volume Selective Excitation: A Novel Approach to Topical NMR", W. P. Aue, S. Muller, T. A. Cross, and J. Seelig, J.

Mag. Reson. Vol. 56, pp. 350-354, 1984; "Selective Spatial Presaturation of Regions of Tailored Shape", S. Singh, W. Brody, SMRM Book of Abstracts, 1992. These techniques generated a series of small RF pulses which summed together to produce the desired resonance excitation. The excitation region was rotated about the isocenter or other selected point such that there was a constructive superposition at a cylinder through the axis of rotation. The pulses were spread over the other remainder of the region providing negligible superpositions at other points, i.e., negligible resonance excitation.

Brief Summary Text (7):
One of the problems with the creation of a localized region of excitation by the superposition of RF pulses is that the technique is quite time consuming. Further gradient spoilers are commonly required between the individual RF pulses to insure that artifacts to not intrude in the image. The spoiler pulses increase the total time even more. Because the RF pulses were commonly identical and only the gradient direction was changed, excitation outside the volume of interest frequently occurred. Excitation outside the volume of interest could be suppressed by keeping the RF tip angle very low, but low tip angles increase the length of the pulse train even longer.

Brief Summary Text (8):
Other works used a single RF pulse in the presence of a time varying magnetic field gradient. See, "Off-Axis Spatial Localization of Frequency Modulated Nuclear Magnetic Resonance Rotating.rho. Pulses", C. J. Hardy, P. A. Bottomley, P. B. Roemer, J. Appl. Phys., Vol. 64, pp. 4741-4743, 1988; "K-Space Analysis of Small-Tip-Angle Excitation", J. Pauly, D. Nishimura, and A. Macovski, J. Mag. Reson., Vol. 81, pp. 43-56, 1989; U.S. Pat. No. 4,985,677 of J. Pauly; and U.S. Pat. No. 5,025,216 of Pauly and Nishimura. In these techniques, the intensity of the RF pulse and the intensity of the gradient field in two dimensions was combined to produce excitation which was localized in two dimensions.

Brief Summary Text (9):
By considering the RF and gradient coils together, a cleaner profile excitation was achieved, but at the expense of far more complicated radio frequency and gradient waveforms. The excitation was tailored to a specific point in space, typically the isocenter of the magnetic field gradients. Moving the region required recalculation of at least the phase profile of the radio frequency signal.

Brief Summary Text (10):
Others have combined portions of the two abovementioned techniques to decompose trajectories into a series of concentric circles or concentric squares. Other radial patterns, pinwheels, and Lissajous figures have also been used for excitation. These techniques require that suitable attention be paid to the homogeneous coverage of the frequencies of interest. See "Correcting for Non-Uniform K-Space Sampling in Two-Dimensional NMR Selective Excitation", C. J. Hardy, H. E. Cline, P. A. Bottomley, J. Mag. Reson., Vol. 87, pp. 639-645, 1990and U.S. Pat. No. 5,105,152 of J. Pauly.

Brief Summary Text (11):
These two techniques unified and optimized the RF requirements for the various trajectories. Identical RF pulses were provided for each spoke of a radial or pinwheel trajectory. Similar RF pulses were applied for each concentric square or circle. Again, the point of selective excitation was controlled by the phase of the RF pulses requiring recalculation of the RF pulse phase to shift the selective excitation region.

Brief Summary Text (13):
In order to limit the region of selective excitation along the third direction, the Aue, et al. and the Crespigny, et al. articles suggested the creation of three-dimensional excitation profiles by a series of identical RF pulses applied in the presence of different magnetic gradient fields. This again required a relatively long duration because gradient ramping must occur between successive pulses. Further, these methods disturbed spins outside of the 3D volume, disturbing their equilibrium condition.

Brief Summary Text (14):
Another technique for limiting the field of excitation in three dimensions was described in "New Spatial Localization Method Using Pulse High-Order Field Gradients (SHOT: Selection with High-Order gradient)", C. H. Ooh, S. K. Hilal, Z. H. Cho, and

I. K. Mun, Mag. Reson. Med., Vol. 18, pp. 63-70, 1991. This technique required high order, i.e. non-linear, pulsed magnetic field gradients to perform the volume selection. Selecting these gradients was again computationally intensive.

Brief Summary Text (15):
Another technique for limiting the excitation region was described in "A Three-Dimensional.pi.Pulse", J. Pauly, D. Nishimura, A. Macovski, SMRM 10th Annual Meeting, Book of Abstracts, Vol. 2, p. 493, 1991. This technique extended the two-dimensional pulse sequence of the previously discussed Pauly, Nishimura, and Macovski article in a third dimension but retained many of the drawbacks discussed above. Further, this technique required an inversion pulse in each repetition rather than an excitation pulse. That is, in order to control the localized excitation region in three dimensions, the prior art performed a succession of two-dimensional localization techniques in adjoining planes.

Brief Summary Text (16):
The present invention provides a new and improved magnetic resonance imaging and spectroscopy technique which facilitates limiting a region of excitation in three dimensions and which facilitates positioning a two or three-dimensional localized excitation region.

Brief Summary Text (18):
In accordance with one aspect of the present invention, a method of exciting magnetic resonance in a limited region is provided. A series of radio frequency pulses and a series of x and y-gradient pulses are applied such that a k-space trajectory of resonance excitation follows a piecewise linear spiral trajectory. The sum of the RF pulses produces a desired net tip angle.

Brief Summary Text (19):
In accordance with another aspect of the present invention, z-gradient pulses are applied in addition to the x and y-gradient pulses such that the k-space trajectory includes a plurality of piecewise linear trajectories among corners of an octahedral.

Brief Summary Text (20):
In accordance with another aspect of the present invention, a frequency offset is applied concurrently with the radio frequency and gradient pulses to shift the location of excitation within the examination region.

Brief Summary Text (21):
In accordance with a more limited aspect of the present invention, the frequency offset includes applying a series of gradient field pulses along one of the x, y, and z-axes.

Brief Summary Text (22):
In accordance with another aspect of the present invention, the series of gradient pulses along each axis diminishes linearly with each repetition such that the piecewise k-space trajectory spirals inward and wherein the offset pulses diminish in amplitude analogously.

Brief Summary Text (23):
In accordance with another aspect of the present invention, a method of exciting magnetic resonance in a three-dimensionally limited region is provided. A series of radio frequency pulses is applied in a duration comparable with a duration for exciting magnetic resonance in conventional magnetic resonance experiments, the sum of the series of magnetic resonance pulses controlling the magnetic resonance tip angle. Concurrently with the series of radio frequency pulses, applying a series of gradient pulses are applied along x, y, and z-axes, the x, y, and z-gradient pulses decreasing in amplitude with each repetition such that a k-space trajectory spirals in three dimensions analogous to the winding pattern of a ball of string.

Brief Summary Text (24):
One advantage of the present invention is that it enables the location of the limited magnetic resonance excitation region to be shifted physically without recalculating and adjusting phase of the RF signal.

Brief Summary Text (25):
Another advantage of the present invention is that it facilitates defining the limited region of magnetic resonance excitation in three dimensions.

Brief Summary Text (27):
Another advantage of the present invention is that it enables magnetic resonance excitation to be limited to a selected area without causing artifacts in other areas.

Drawing Description Text (3):
FIG. 1 is a diagrammatic illustration of a magnetic resonance imaging device in accordance with the present invention;

Drawing Description Text (4):
FIGS. 2A, 2B, 2C and 2D are illustrative of the series of RF pulses, the series of x-gradients, the series of y-gradients that cause the excitation to follow the trajectory of FIG. 3 in k-space, and FIG. 2D illustrates frequency offsets for positioning the region of limited magnetic resonance excitation;

Drawing Description Text (6):
FIG. 4 is a superimposition of the RF and gradient pulses of FIGS. 2A-2D;

Drawing Description Text (9):
FIGS. 7A, 7B, 7C, and 7D illustrate a series of radio frequency pulses which make up the RF excitation pulse and a series of x, y, and z-gradient pulses which cause the excitation to follow the spiral trajectory of FIG. 6;

Drawing Description Text (10):
FIG. 8 is a superimposition of RF and gradient pulses analogous to FIGS. 7A-7D but for a six layer octahedral trajectory;

Drawing Description Text (11):
FIG. 9 is a series of offset gradient pulses for shifting the center of excitation along the x-axis of FIG. 7B;

Drawing Description Text (12):
FIG. 10 is a series of RF and gradient pulses for defining a spherically spiralling k-space trajectory analogous to a ball of string.

Detailed Description Text (2):
With reference to FIG. 1, a main magnetic field control means 10 controls superconducting or resistive magnets 12 such that a substantially uniform static magnetic field is created along a z-axis through an examination region 14. A magnetic resonance echo generating means applies a series of RF and magnetic field gradient pulses to cause magnetic resonance imaging and spectroscopy sequences, such as field echo sequences, echo-planar sequences, segmented k-space sequences, and the like. More specifically, gradient pulse amplifiers 20 apply current pulses to gradient coils 22 to create magnetic fields along x, y, and z-axes of the examination region 14. A digital radio frequency transmitter 24 transmits radio frequency pulses, including RF pulses composed of a packet of immediately contiguous pulses of short duration, to an RF coil 26 to transmit RF pulses into the examination region. RF pulses are used to saturate, excite resonance, or manipulate resonance in selected portions of the examination region. A digital radio frequency receiver 28 receives radio frequency magnetic resonance signals emanating from the examination region. The resonance signals are picked up by the RF coil 26 or by surface coils (not shown).

Detailed Description Text (3):
A sequence control means 30 controls the gradient pulse amplifiers 20, the digital transmitter 24, and the digital radio frequency receiver 28. More specifically, the control means 30 includes a sequence control means 32 which causes a digital transmitter to transmit appropriate RF pulses and causes the gradient pulse amplifiers 20 to apply appropriate gradient pulses for a selected magnetic resonance imaging or spectroscopy sequence. A sequence memory 34 stores a plurality of magnetic resonance imaging or spectroscopy sequences as are known in the art. Many of the sequences will use conventional RF pulses. A limited resonance excitation selection pulse control means 36 selectively accessed by the sequence control means 32 provide appropriate RF and gradient pulse controls for limiting the RF excitation to a selectable small region. An operator control panel or means 40 includes an appropriate keyboard or other means 42 for selecting among the plurality of sequences in the sequence memory 34. A limited resonance excitation region selection means 44 includes a keyboard, menu, or other appropriate means for selecting the

size 46 of the limited region of excitation and means 48 for selecting the location of limited excitation within the examination region.

Detailed Description Text (4):
With reference to FIGS. 2A, 2B, and 2C, and continuing reference to FIG. 1, the limited region resonance excitation means 36 includes a radio frequency signal control means 50 for producing a series of very small flip angle RF pulses 52 as illustrated in FIG. 2A. The sequence of small pulses span about 10 msec., i.e. the duration of a conventional RF excitation pulse. The area underneath the curve of FIG. 2A determines the flip angle of the RF pulse. By increasing the amplitude of the FIG. 2A RF pulse, larger flip angles are obtained. An x-gradient control means 54 and a y-gradient control means 56 cause the gradient amplifiers to generate magnetic field gradients 58x and 58y as illustrated in FIGS. 2B and 2C, respectively.

Detailed Description Text (5):
With reference to FIG. 3, the RF and gradient pulse sequence described in FIGS. 2A, 2B, and 2C cause a square spiral k-space trajectory 60. FIG. 4 is a superimposition of FIGS. 2A, 2B, and 2C. Each cycle 62 corresponds to the trajectory moving along a first four sides 64a, 64b, 64c, 64d of the square spiral of FIG. 3. Note in FIG. 4 that each pulse of the series of RF pulses in cycle 62 is applied with a different one of four x and y-gradient combinations, thus causing movement along a corresponding one of the four sides of the trajectory. Because the gradients decrease in amplitude with each cycle, the trajectory spirals inward to form the square spiral trajectory.

Detailed Description Text (10):
T is the total time of the gradient waveform;

Detailed Description Text (13):
the square spiral and are defined as follows: ##EQU1## With this gradient and RF pulse sequence, excitation is limited to a small region at the isocenter of the examination region.

Detailed Description Text (14):
With reference to FIG. 2D, unlike the prior art which requires recalculation of the phase or exponential components of the RF signal, the present invention shifts the position of limited excitation within the examination region by applying frequency offset profile 66. The frequency offset profile is calculated with the same equations, except that it is rotated 45.degree. from the gradient waveform, i.e.: ##EQU2##

Detailed Description Text (15):
The radio frequency pulse B.sub.1 (t) is calculated on a point by point basis from the k-space trajectory as follows:

Detailed Description Text (19):
For the k-space coverage illustrated in FIG. 3 with an eight turn square spiral trajectory, the gradient waveforms of FIGS. 2B and 2C are calculated by "unwrapping" as a function of time. The radio frequency waveform is then calculated from the trajectory. With reference again to FIG. 4, close inspection of the RF waveform allows identification of a series of RF pulses, each of which are associated with a particular leg of the square spiral profile. From this, the frequency offset profile 66 of FIG. 2D is created. The amount of offset or spatial displacement is adjusted by increasing the size, particularly the amplitude, of the frequency offsets 62. Movement of the resultant two-dimensional excitation pattern is straightforward. The frequency offset is zero on paths through the first and third quadrant, negative in the second quadrant, and positive in the fourth quadrant of FIG. 3. In the illustrated embodiment of FIGS. 2A-2D, offset is negative where the x-gradient goes negative and the offset is positive when the x-gradient goes positive. In this manner, the frequency offset 62 performs an analogous function in a modulated fashion in this two-dimensional case as it performs in a static fashion in a one-dimensional or normal slice select case. The center of the excitation region is shifted along the x-axis by a distance indicated by the operator on the location selection means 48. Exact placement of the subregion of excitation is accomplished by rotating the displacement axis, in the example of FIG. 2D the x-axis, along which the frequency offset 62 is applied to align with the desired excitation region. Once the coordinate system in the examination region is rotated, the amplitude of the offset pulse profile is adjusted by an offset control means 68 translate the

subregion within which resonance is excited the selected distance along the offset axis.

Detailed Description Text (20):
Although described in terms of a square spiral, it is to be appreciated that other trajectories which excite two dimensions in k-space with a series of linear sub-trajectories can be translated analogously. Moreover, analogous results can be achieved in three dimensions. That is, with the two-dimensional trajectory, resonance is excited in a parallelepiped region which extends through the region of interest and all the way across the examination region. By rotating or spiraling the trajectory in three dimensions, resonance excitation can be limited to a region which is defined in three dimensions, e.g. a volume which approaches an octahedron. When the trajectory of the three-dimensional spiral is a series of linear subdirectories, the same translation procedure can be applied to adjustably position the subregion of resonance excitation without adjusting the phase or other exponential terms in the RF pulse.

Detailed Description Text (21):
With reference to FIG. 5, in the preferred three-dimensional embodiment, the k-space trajectory follows an octahedral spiral. FIG. 5 illustrates a single coverage of the octahedral without spiraling inward. Preferably, the gradient amplitudes are decreased with each repetition such that the three-dimensional octahedral spiral of FIG. 6 is created.

Detailed Description Text (22):
With reference to FIGS. 7A, 7B, 7C, 7D, and 8, the limited region excitation means generates an RF pulse 70 of about 10 msec. as illustrated in FIG. 7A. The x-gradient control means 54 and the y-gradient control means 56 apply x and y-gradients 72x, 72yas illustrated in FIGS. 7B and 7C, respectively. A z-gradient means 74 causes a series of z-gradients 72z to be applied as illustrated in FIG. 7D. As can be seen from FIG. 8 which is the superimposition of the RF and gradient pulses of FIGS. 7A-7D but with six cycles instead of four cycles, there are twelve RF pulses for each cycle 62 of the gradients to cause the trajectory to follow the twelve linear subtrajectories between apices of the octahedron of FIG. 6. With the present preferred embodiment, each apex is visited twice per cycle, once during the first six legs of the trajectory and again during the second six legs of the trajectory. In the FIG. 7A-7D embodiment, there are four cycles of the gradients such that the trajectory decays along four progressively smaller octahedral layers. In the embodiment of FIG. 8, there are six cycles such that the trajectory decays along six progressively smaller octahedral layers.

Detailed Description Text (24):
K-space k(t) is limited to gradient space G(t) by: ##EQU3## Because all three coordinate axes in k-space are related to the three Cartesian axes of gradient space by a simple rotation, the trajectories can be described in gradient space.

Detailed Description Text (25):
Any leg of the gradient trajectory can be expressed in terms of the amplitude of the two contributing gradients i and j:

Detailed Description Text (29):
T is the total time of the gradient waveform;

Detailed Description Text (33):
The RF pulse, with a Gaussian shape, is calculated on a point by point basis from the three-dimensional gradient space trajectory by:

Detailed Description Text (39):
With reference to FIG. 9, the location of the limited resonance excitation subregion is selectively positioned with offset profiles 76 analogous to frequency offset profiles 66 illustrated in FIG. 2D. The analogous frequency offset profiles 76 are applied in the three-dimensional case in accordance with a location input by the operator with the location selection means 48. The offset axis is rotated into alignment with the selected location and the amplitude of the frequency offset profiles 76 are adjusted in accordance with the selected displacement along the rotated axis from the isocenter. The size of the subregion of excitation can be adjusted by adjusting amplitude of the gradient waveforms. Additional octahedral spirals may be added to cause a more homogeneous coverage of k-space.

Detailed Description Text (40):
As yet another alternative, the three-dimensional trajectory may be than other than a piecewise linear trajectory. For example, a curvilinear trajectory such that R.sup.2= (G.sub.x.sup.2+G.sub.y.sup.2+G.sub.z.sup.2), where the magnitude of R follows that of the equi-angular spiral, may also be used. This changes the octahedral spiral to a spherical spiral which could follow the spherically spiral windings found on a ball of yarn or the interior or a baseball. FIG. 10 illustrates appropriate gradient and RF pulses to create a spherically spiral trajectory. Of course, with the spherically spiral trajectory, movement of the subregion of excitation requires shifting the phase of the RF pulse rather than applying frequency offset profiles pulses.

Detailed Description Text (42):
With reference again to FIG. 1, in one mode of operation, the operator selects a conventional flow imaging sequence and selects an adjacent region, such as the region through a major artery, to be saturated. Each repetition of the conventional flow imaging sequence is preceded by a selective saturation pulse. That is, the selective

Detailed Description Text (43):
saturation pulse includes an RF pulse and gradient sequence as described above to-- saturate the selected region, e.g. through the adjacent artery. As each magnetic resonance echo is received, it is conveyed to a buffer memory 80 and digitized by an analog-to-digital converter 82. The digitized data lines are stored in a data memory 84. Once a full set of data is collected, it is reconstructed by an inverse two-dimensional Fourier transform or other conventional image reconstruction means 86 into an electronic image representation. The electronic image representation, which is stored in an image memory 88, is converted by a video processor 90 into appropriate format for display on a video monitor 92.

Detailed Description Text (44):
In another mode of operation, the present invention is used to limit the region of examination. More specifically, the operator selects a conventional magnetic resonance imaging sequence and designates the region to be imaged. In the conventional magnetic resonance imaging sequence, each RF excitation pulse is replaced with an RF pulse and gradient as described above. By using the size and location adjustment means 46, 48, the operator can select the limited region within which resonance is to be excited. The resultant magnetic resonance echo signals emanating from the limited region are again received by the buffer 80, digitized, and reconstructed into an electronic image representation.

Detailed Description Text (45):
In imaging sequences which use a refocusing RF pulse or other magnetic resonance manipulating RF pulses, one or more of the additional RF pulses may also be configured with the RF and gradient combinations described above. For example, in a spin echo technique, resonance may be excited in a relatively large region. By applying a 180.degree. refocusing pulse to only a limited region using the technique described above, the resultant magnetic resonance echo will be limited to magnetic resonance from the region to which the refocusing pulse was limited. In this manner, region specific imaging is achieved. Analogously, other imaging techniques may utilize the present invention to saturate a limited region, excite resonance in a limited region, manipulate resonance in a limited region, or the like.

Other Reference Publication (1):
"Volume-Selective Excitation: A Novel Approach to Topical NMR", Aue, et al. J. Mag. Reson. vol. 56, pp. 350-354 (1984).

Other Reference Publication (3):
"Correcting for Nonuniform k-Space Sampling in Two-Dimensional NMR Selective Excitation", Hardy, et al., J. Mag. Reson. vol. 87, pp. 639-645 (1990).

Other Reference Publication (4):
"New Spatial Localization Method Using Pulsed High-Order Field Gradients (SHOT: Selection with High-Order Gradient), " Oh, et al., Mag. Reson. in Medicine, vol. 18, pp. 63-70 (1991).

CLAIMS:

1. A method of exciting magnetic resonance in a limited subregion of an examination

region, the method comprising:

creating a static magnetic field through an examination region;

concurrently transmitting a series of temporally contiguous radio frequency pulses and excitation select gradient pulses into the examination region, the series of contiguous radio frequency pulses taken together control a magnetic resonance excitation tip angle, the excitation select gradient pulse and the radio frequency pulses interact to cause magnetic resonance to be excited along a k-space trajectory that follows a piecewise linear spiral.

2. The method as set forth in claim 1 further including applying a series of frequency offset profiles generally concurrent with the excitation select gradient pulses along a first axis, amplitudes of the frequency offset pulses controlling shifting of the excitation subregion along the firs axis.

4. The method as set forth in claim 3 wherein the excitation select gradient pulses are applied along three mutually orthogonal axes such that the trajectory follows a three-dimensional piecewise linear spiral.

6. The method as set forth in claim 1 wherein each radio frequency pulse of the series of radio frequency pulses has the same duration and wherein the excitation select gradient pulses include:

x-gradient pulses which oscillate in polarity with a periodicity such that each cycle of the x-gradient pulses is an integer multiple of radio frequency pulses; and

y-gradient pulses which oscillate in polarity with a periodicity such that each cycle of the y-gradient pulses is an integer multiple of radio frequency pulses.

7. The method as set forth in claim 6 wherein the x and y-gradient pulses diminish linearly in amplitude.

8. The method as set forth in claim 7 further including displacing the limited subregion along one of the first and second axes by applying a positive frequency offset profile of a positive polarity concurrently with each positive gradient pulse along the selected axis and applying a negative frequency offset profile concurrently with each excitation select gradient pulse along the selected axis, the positive and negative frequency offset profiles each having substantially the same duration as one of the radio frequency pulses.

9. The method as set forth in claim 8 wherein the series of excitation select gradient pulses further includes a series of z-gradient pulses.

10. The method as set forth in claim 7 wherein the excitation select gradient pulses include a series of z-gradient pulses, the z-gradient pulses cyclically alternating polarity with a periodicity which is an integer ratio of the radio frequency pulses, the z-gradient pulses diminishing linearly in amplitude.

11. A method of exciting magnetic resonance in a limited subregion of an examination region, the method comprising:

creating a static magnetic field through an examination region;

concurrently transmitting a series of radio frequency pulses and excitation location selection gradient pulses into the examination region, the radio frequency pulses each having a common duration and being immediately temporally contiguous such that the combination of the radio frequency pulses taken together control a magnetic resonance tip angle, the series of excitation location selection pulses including a series of x-gradient pulses including positive and negative x-gradient pulses having a fixed cyclic periodicity, which x-gradient periodicity is an integer multiple of the radio frequency pulses, the x-gradient pulses having amplitudes which diminish linearly over a temporal duration of the radio frequency pulse series, a series of y-gradient pulses including positive and negative y-gradient pulses having a fixed cyclic periodicity, which y-gradient periodicity is an integer multiple of the radio frequency pulses, the y-gradient pulses having amplitudes which diminish linearly over the temporal duration of the radio frequency pulse series, a series of z-gradient pulses including positive and negative z-gradient pulses having a fixed

cyclic periodicity, which z-gradient periodicity is an integer multiple of the periodicity of the radio frequency pulses, the z-gradient pulses having amplitudes which diminish linearly over the temporal duration of the radio frequency pulse series, whereby magnetic resonance is excited along a k-space trajectory which spirals symmetrically inward in three dimensions.

12. The method as set forth in claim 11 further including applying a series of frequency offset profiles concurrently with gradient pulses of a selected one of the x, y, and z-gradient pulse series to displace the limited region of excitation along the selected axis.

13. The method as set forth in claim 12 further including adjusting the amplitude of the frequency offset profile to control a distance along the selected axis which the limited subregion is displaced.

14. The method as set forth in claim 12 wherein the series of frequency offset profiles diminish linearly in amplitude over the duration of the radio frequency pulse series.

15. A method of exciting magnetic resonance in a limited subregion of an examination region, the method comprising:

creating a static magnetic field through an examination region;

concurrently transmitting a series of temporally contiguous radio frequency pulses having a radio frequency pulse series periodicity and applying a series of excitation subregion selection gradient pulses into the examination region along at least first and second axes, the series of excitation subregion selection gradient pulses having a periodicity which is an integer multiple of the radio frequency pulse series periodicity, the series of contiguous radio frequency pulses and the series of excitation subregion selection gradient pulses interacting to cause magnetic resonance to be excited along a k-space trajectory that follows a piecewise linear spiral;

displacing the selected subregion within which magnetic resonance is excited along a selected one of the axes by applying a frequency offset profile concurrently with each excitation subregion selection gradient pulse along the selected axis, each frequency offset profile being concurrently with and having the same duration as one the radio frequency pulse pulses.

17. The method as set forth in claim 16 wherein the amplitudes of the excitation subregion selection gradient pulses and the frequency offset profile diminish linearly over the duration of the series of radio frequency pulse series.

18. The method as set forth in claim 16 wherein the step of applying the series of excitation location selection gradient pulses further includes cyclically applying gradient pulses along a third axis with a cyclic periodicity which is the same integer multiple of the radio frequency pulse series periodicity as the cyclic periodicity of the gradient pulses along the first and second axes, the radio frequency pulses and the excitation subregion selection gradient pulses along the three axes being selected such that the magnetic resonance is excited along a k-space trajectory which follows a three-dimensional piecewise linear spiral.

19. An apparatus for exciting magnetic resonance in a limited subregion of an examination region, the apparatus comprising:

a means for creating a static magnetic field through an examination region;

a means for concurrently transmitting a series of temporally contiguous radio frequency pulses and for applying a series of excitation location selection gradient pulses along at least first and second orthogonal axes into the examination region such that the series of radio frequency pulses and the series of excitation location selection gradient pulses interact to cause magnetic resonance to be excited along a k-space trajectory that follows a piecewise linear spiral.

20. An apparatus for exciting magnetic resonance in a limited subregion of an examination region, the apparatus comprising:

a means for creating a static magnetic field through an examination region;

means for transmitting a series of radio frequency pulses into the examination region, the radio frequency pulses each having a common duration and being immediately temporally contiguous such that the combination of the radio frequency pulses taken together control a magnetic resonance tip angle;

a means for applying excitation subregion selection gradient pulses across the examination region, the series of excitation subregion selection pulses including a series of x-gradient pulses including positive and negative x-gradient pulses, a series of y-gradient pulses including positive and negative y-gradient pulses and a series of z-gradient pulses including positive and negative z-gradient pulses;

a control means for controlling the means for transmitting radio frequency pulses and the gradient applying means such that the x, y, and z-gradient pulse series have a periodicity which is an integer multiple of the radio frequency pulse duration, the x, y, and z-gradient pulses having amplitudes which diminish linearly over the temporal duration of the radio frequency pulse series, whereby magnetic resonance is excited along a k-space trajectory which spirals symmetrically inward in three dimensions.

21. An apparatus for exciting magnetic resonance in a limited subregion of an examination region, the apparatus comprising:

a means for creating a static magnetic field through an examination region;

a means for transmitting a series of temporally contiguous radio frequency pulses each of a common duration into the examination region;

a means for applying a series of limited subregion selection gradient pulses across the examination region along at least two axes;

a control means for controlling the radio frequency transmitting means and the gradient applying means such that the series of limited subregion selection gradient pulses have a periodicity which is an integer multiple of the common duration of the radio frequency pulses, the series of contiguous radio frequency pulses and the series of limited subregion selection gradient pulses interacting to cause magnetic resonance to be excited along a k-space trajectory that follows a piecewise linear spiral;

a means for displacing the limited subregion along a selected one of the axes, the displacing means controlling the gradient applying means and the radio frequency pulse transmitting means to apply an offset gradient pulse concurrently with each limited subregion selection gradient pulse along the selected axis.

End of Result Set

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L28: Entry 2 of 2 File: USPT Aug 20, 1991

DOCUMENT-IDENTIFIER: US 5041789 A
TITLE: Magnetic-resonance instrument employing barcode experiment specification

Abstract Text (1):
A multi-experiment magnetic-resonance instrument such as a programmable pulse/Fourier-transform nuclear-magnetic-resonance ("NMR") spectrometer, an electron-paramagnetic-resonance spectrometer, or a magnetic resonance tomographic imaging device, capable of performing any one of a plurality of magnetic-resonance measurement sequences selected by a user and comprising: a magnet for generating a magnetic field; a probe having radio-frequency coupling circuitry positionable in the magnet; a radio-frequency generator/transmitter connected to the coupling circuitry of the probe; a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe; a digitized-signal averager/processor connected to the receiver/digitizer; a programmable instrument controller having measurement-sequence control-program storage; a barcode reader connected to the instrument controller; and at least one measurement-sequence-selection barcode table having a plurality of barcode-encoded measurement-sequence data words arranged on it.

Brief Summary Text (2):
The present invention concerns a multi-experiment magnetic-resonance instrument--such as a programmable pulse/Fourier-transform nuclear-magnetic-resonance ("NMR") spectrometer--capable of performing any one of a plurality of magnetic-resonance measurement sequences selected by a user. As used herein, the term "magnetic-resonance instrument" includes, for example, NMR spectrometers, electron-paramagnetic-resonance spectrometers, or magnetic-resonance tomographic imaging devices.

Brief Summary Text (4):
Conventional pulse/Fourier-transform NMR spectrometers are generally capable of performing a wide variety of magnetic-resonance measurement sequences. Such magnetic-resonance measurement sequences typically involve subjecting a sample in a magnetic field to pulsed or otherwise time-varying radio-frequency fields at one or more frequencies; amplifying, detecting, and digitizing the magnetic-resonance signals elicited from the sample by the radio-frequency fields; and processing the resulting digitized signals by Fourier transformation or other data processing operations for analysis and display. As used herein, the term "magnetic-resonance measurement sequence" can refer to sequences in which two or more operations in a magnetic resonance experiment which are carried out simultaneously--such as, for example, simultaneous irradiation of a sample at two frequencies--as well as operations which follow one another in time.

Brief Summary Text (5):
A conventional pulse/Fourier-transform NMR spectrometer ordinarily includes a radio-frequency pulse-generator/transmitter and a pulse programmer for controlling the pulse-generator/transmitter to produce sequences of radio-frequency excitation pulses. In general, each pulse in such a pulse sequence has a well-defined shape, intensity, duration, phase, and separation from neighboring pulses. Different pulse sequences are generally required for different magnetic-resonance measurement sequences.

Brief Summary Text (6):
A magnetic-resonance measurement sequence also typically involves digitizing at timed intervals the magnetic-resonance signals excited by the sequence of

radio-frequency pulses, accumulating digitized signals from a number of measurement runs for signal averaging, and digitally manipulating the accumulated digitized signals by Fourier transformation or other algorithm. For this reason, conventional pulse/Fourier-transform NMR spectrometers generally include a data processor which may be programmed to perform specified data-processing operations to analyze the magnetic-resonance signals excited by a particular pulse sequence.

Brief Summary Text (7):
Among the factors which can influence the selection of a particular pulse sequence and a particular set of data processing operations is the nature of the sample to be investigated. Thus, each time a new sample is introduced into the NMR spectrometer for analysis, it is ordinarily necessary for a user to enter instructions into the spectrometer specifying the measurement sequence to be used. NMR spectrometers configured for automatic operation may include an automatic sample changer for inserting a series of samples one-by-one into and withdrawing them from the spectrometer automatically. The user must ordinarily enter instructions into the spectrometer to program the operation of the automatic sample changer as well as to specify the measurement sequence to be used for each of the samples.

Brief Summary Text (8):
Modern pulse/Fourier-transform NMR spectrometers are capable of performing an almost bewildering variety and number of measurement sequences when account is taken of the many different NMR measurement experiments which can be performed and the many different nuclei and combinations of nuclei on which such experiments can be carried out. The measurement sequences to obtain the NMR spectra of different nuclei constitute different sequences since a user must specify the identity of the nucleus--or equivalently, its resonance frequency--to the spectrometer. Moreover, the number of such measurement sequences is increased inasmuch as the NMR spectra of the various nuclei can be obtained with or without the application of radio-frequency decoupling fields for effectively eliminating interactions with other types of nuclei in the sample. The number of measurement sequences for obtaining NMR spectra is further increased in that additional radio-frequency fields may be applied to suppress interfering resonance lines from solvents in which the sample is dissolved. Different measurement sequences are required to determine relaxation times of individual resonance lines using sequences of pairs of radio-frequency pulses of differing widths--for example, a 180.degree. pulse followed by a 90.degree. pulse--and incrementally varying the time interval between the pulses of the pair. In still other measurement sequences of which many modern pulse/Fourier spectrometers are capable, two-dimensional spectra may be obtained which reveal interactions between different nuclei in a sample. Polarization may be transferred from one group of nuclei to another by measurement sequences such as an experiment referred to as the distortionless enhancement by polarization-transfer experiment--also referred to as the "DEPT" experiment. In general, a user must specify which of these and many other measurement sequences the pulse/Fourier-transform spectrometer is to perform on a sample in a given experiment.

Brief Summary Text (9):
In addition, conventional pulse/Fourier-transform NMR spectrometers are capable of locking the magnetic field of the spectrometer to resonance signals of a variety of nuclei in a locking channel. Optimizing the locking typically involves adjusting parameters such as the power of a radio-frequency field in the locking channel of the spectrometer, the gain of a receiver in the locking channel and the phase of a magnetic-resonance signal used for locking. A user must ordinarily specify at least the nucleus and compound from which the locking signals are to be obtained, and, in many spectrometers, may specify the values of the locking-channel parameters as well.

Brief Summary Text (10):
To produce a highly homogeneous magnetic field typically required in magnetic resonance spectroscopy, currents through various magnetic-shim coils must be adjusted. Modern high-resolution magnetic-resonance spectrometers in general perform such field shimming adjustments automatically. However, different samples and different experimental procedures may require different strategies for optimizing the shimming. Consequently, the user may have to specify the shimming procedure to be used in a given experiment.

Brief Summary Text (11):
A user is faced with additional parameters to specify which relate to collecting

magnetic-resonance signal data in specifying a measurement sequence for a conventional pulse/Fourier-transform NMR spectrometer. For example, the phase, the gain, and the bandwidth of a receiver channel of the spectrometer must be specified for each measurement sequence. In addition, the interval between the times the signal is sampled must be specified.

Brief Summary Text (12):
The user of a pulse/Fourier-transform NMR spectrometer must provide further specifications in connection with processing the digitized magnetic-resonance signals for the display and analysis. For example, the user typically must specify selections for the measurement sequence in connection with correcting phase errors, compensating for base-line drift, and defining regions for integrating line intensities. In addition, the media on which the resulting spectra are to be displayed must be specified, along with scaling parameters and whether or not spectral lines will be identified digitally.

Brief Summary Text (13):
Largely as a result of the great number of different items which a user must specify in performing even routine magnetic-resonance measurements on a modern pulse/Fourier-transform NMR spectrometer, such spectrometers tend to be intimidating to users who may desire the results of magnetic-resonance measurements, but who are not experts in magnetic-resonance measurement technology.

Brief Summary Text (14):
Attempts have been made in the past to simplify the operation of NMR spectrometers so that magnetic- resonance measurements could be carried out by persons who are not expert in magnetic-resonance measurement technology. In certain cases such attempts have simplified spectrometer operations somewhat, but there remains room for improvement.

Brief Summary Text (15):
For example, a series of pulse/Fourier-transform NMR spectrometers commercially available from Bruker Instruments Inc. of Billerica, Massachusetts under the trade designation "AM"-series spectrometers has been capable of performing a variety of magnetic-resonance measurements on a number of different nuclei. Each "AM"-series spectrometer has included a computer for controlling the spectrometer as well as for storing and processing the signals obtained from the magnetic-resonance experiments. Software has been available for the computer which, on the one hand, has allowed a specialist in magnetic-resonance measurement technology to have access to the full range of the capabilities of the spectrometer, and which, on the other hand, has permitted less-experienced users to perform routine experiments without requiring them to specify the details of spectrometer operation. A menu of descriptive information has been provided which was invoked by typing a "HELP" command on the keyboard. A menu-driven procedure has been available for specifying experiments for obtaining routine NMR spectra--including certain two-dimensional spectra which directed the user to supply necessary spectrometer-control instructions through a dialogue procedure. The selected spectrometer-control instructions served to invoke control routines in the computer for controlling the operation of the spectrometer. Appropriate sets of parameters were retrieved from a magnetic disk for performing the specified experiment.

Brief Summary Text (16):
For entering spectrometer-control instructions from a user, the "AM"-series of NMR spectrometers have heretofore included a terminal in form of a console having a keyboard, a display and an interface/control system. The display of the terminal was capable of displaying the menu of instructions from which the user could select by typing on the keyboard and displaying the instructions so selected. However, the typing of a series of spectrometer-control instructions tended to be an exacting task which too often led to errors. Although certain typing errors could be detected and rejected by the terminal interface/control system when they were recognizable as syntax errors, correctly-typed, but inappropriate instructions could not in general be detected and tended to cause trouble since such instructions could launch the spectrometer on sequences of inappropriate operations.

Brief Summary Text (17):
A mouse for controlling the position of a cursor on the display has also been available for spectrometer-control instruction input in the "AM"-series of spectrometers. Another conventional pulse Fourier-transform spectrometer has employed a light pen and a CRT for entering spectrometer-control instructions. A

conventional magnetic-resonance tomographic imaging device heretofore available has used a touch-sensitive CRT for entering instructions for controlling the device.

Brief Summary Text (18):
The computer software for the "AM"-series of NMR spectrometers also includes a password system which is intended to prevent one user from accessing or destroying the files of another user. In addition, the software password system is programmed to prevent users other than a designated system manager from altering the system software and the basic interface between the software and the spectrometer. However, if an unauthorized person learns the password of the system manager, the person can be in a position to make changes to the fundamental system software and software/spectrometer interface without the system manager's knowledge. Moreover, even an inexperienced user using his or her own password is permitted to bypass the menu-driven procedure for routine experiments and directly alter spectrometer settings and experimental parameters. A subsequent user can experience error, confusion, and delay when a prior user changes spectrometer settings and experimental parameters to nonstandard values and does not return them to expected standard values prior to leaving the spectrometer for the subsequent user.

Brief Summary Text (19):
Among the features heretofore available on the Bruker "AM"-series NMR spectrometer was an automated sample changer. The sample changer had an array of sample holders for holding sample tubes containing samples to be analyzed. The sample tubes were labelled with barcoded labels. The sample changer included a barcode reader mounted on the changer which was capable of reading the labels of the sample tubes one at a time. The sample changer was adapted to transfer selectively a sample tube identified by a predetermined label to the magnet.

Brief Summary Text (20):
European published patent application No. 86302595.3, published Oct. 15, 1986 under publication No. 0197791, disclosed an automated apparatus for presenting samples to an NMR spectrometer. The apparatus employed a reflective coding label affixed to a sample carrier for identifying the sample and prescribing the operating parameters of the spectrometer. An LED light source and a photodiode optical detector were mounted in the probe of the spectrometer adjacent to a sample-carrier-receptacle cavity for reading the reflective coding labels of sample carriers inserted in the cavity. Evidently, to make any change in the operating parameters prescribed by a reflective coding label for a sample required the preparation of a new reflective coding label, removing the label previously affixed to the sample carrier, and affixing the new label in place of the previous label, a major inconvenience.

Brief Summary Text (22):
We have invented a magnetic-resonance instrument which provides for convenient input of measurement-sequence specification information in which the danger of input errors is substantially reduced and which avoids problems of the prior art noted above.

Brief Summary Text (23):
Broadly, the magnetic-resonance instrument of the invention comprises a magnet for generating a magnetic field and a probe positionable in the magnet for positioning test matter to be analyzed in the magnetic field. Such test matter could include, for example, a sample of a chemical compound whose NMR spectrum is desired or a body to be imaged tomographically. The probe includes radio-frequency coupling circuitry for coupling radio-frequency signals between the test matter and the coupling circuitry. In the case of an NMR spectrometer, the coupling circuitry may comprise, for example, a solenoidal sample coil. In the case of a magnetic-resonance tomographic imaging device, the coupling circuitry may comprise, for example, a probe-head resonator circuit.

Brief Summary Text (24):
The magnetic-resonance instrument of the invention further comprises a radio-frequency generator/transmitter connected to the coupling circuitry of the probe. The generator/transmitter is capable of generating and amplifying radio-frequency excitation signals for exciting magnetic-resonance signals from the test matter in the probe in accordance with a magnetic-resonance measurement sequence. The timing of the excitation signals is specified by control signals applied to the generator/transmitter.

Brief Summary Text (25):

The magnetic-resonance instrument of the invention further comprises a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe for amplifying and detecting magnetic-resonance signals from the test matter and for digitizing the signals to form digitized magnetic-resonance signals.

Brief Summary Text (26):
The magnetic-resonance instrument of the invention further includes a digitized-signal averager/processor which is connected to the receiver/digitizer. The averager/processor is capable of accumulating and storing digitized magnetic-resonance signals from the receiver/digitizer and digitally processing the stored signals for interpretation and display. Processing operations carried out by the averager/processor are specified by control signals applied to the averager/processor.

Brief Summary Text (27):
The magnetic-resonance instrument of the invention further comprises a programmable instrument controller having measurement-sequence control-program storage for storing a plurality of measurement-sequence control programs. Each measurement-sequence control program specifies one of a plurality magnetic-resonance measurement sequences which the magnetic-resonance instrument is capable of carrying out. As used herein, the term "measurement-sequence control-program" can refer to any program, routine, subprogram or subroutine, or to any collection of programs, routines, subprograms, or subroutines--and to any associated data--which performs an instrument control function for a magnetic-resonance measurement sequence. Associated with each measurement-sequence control program is a digital control-program identifier for identifying the control program. The instrument controller is adapted to recall and execute selectively a measurement-sequence control program identified by a specified control-program identifier to generate control signals for the magnetic-resonance measurement sequence specified by the control program. The instrument controller is connected to the radio-frequency generator/transmitter for applying control signals to the generator/transmitter to specify the timing of the radio-frequency excitation signals generated by the generator/transmitter. The instrument controller is also connected to the digitized-signal averager/processor for applying control signals to the averager/processor to specify processing operations carried out by the averager/processor.

Brief Summary Text (28):
The magnetic-resonance instrument of the invention also includes a barcode reader which is connected to the instrument controller for reading barcode-encoded data words and transmitting signals representative of such data words to the instrument controller. A plurality of barcode-encoded data words define measurement-sequence data words. For each of a plurality of magnetic-resonance measurement sequences which the magnetic-resonance instrument is capable of carrying out, one or more barcode-encoded measurement-sequence data words constitute measurement-sequence specification information sufficient to specify the measurement sequence at least to an extent of permitting the control-program identifier associated with a measurement-sequence control program which specifies the measurement sequence to be identified. The instrument controller is adapted to receive signals from the barcode reader representative of the one or more barcode-encoded measurement data words which constitute measurement-sequence specification information specifying a measurement sequence and to recall and execute the measurement-sequence control program identified by the control-program identifier identified in the measurement-sequence specification information.

Brief Summary Text (29):
Finally, the magnetic-resonance instrument of the invention includes one or more measurement-sequence-selection barcode tables. Each measurement-sequence-selection barcode table has a plurality of barcode-encoded measurement-sequence data words arranged on it. Each barcode-encoded measurement-sequence data word on the barcode table is selectively readable by a user with the barcode reader to transmit signals to the instrument controller representative of the measurement-sequence data word. The measurement-sequence-selection barcode table has a plurality of measurement sequences associated with it which the magnetic-resonance instrument is capable of carrying out. Each of the measurement sequences associated with the barcode table can be specified by magnetic-sequence specification information constituted by one or more of the barcode-encoded measurement-sequence data words included on the barcode table. A user can thus cause the magnetic-resonance instrument to selectively perform a magnetic-resonance measurement sequence specified by one of

the measurement-sequence control programs associated with a measurement-sequence-selection barcode table by reading a corresponding one or more of the barcode-encoded measurement-sequence data words on the measurement-sequence-selection barcode table with the barcode reader.

Brief Summary Text (30):
Preferably, the barcode reader of the magnetic resonance instrument of the invention is a hand-holdable wand. The barcode-reader wand is preferably connected to the instrument controller of the magnetic-resonance instrument by means of a flexible signal-transmission cable for transmitting signals encoding data representative of barcode-encoded data words read with the wand to the instrument controller. A suitable hand-holdable barcode-reader wand is commercially available under the trade designation "HBCS-2300" from the Hewlett-Packard Company of Palo Alto, Calif. In a preferred embodiment, the magnetic-resonance instrument of the invention includes a console having a control panel and the measurement-sequence-selection barcode table is removably attachable to the control panel. The preferred hand-holdable barcode-reader wand is attached to the console by the signal-transmission cable. Alternatively, a fixed-position barcode reader may be installed in a console of a magnetic-resonance instrument of the invention and a barcode table may be read by positioning the table over the reader.

Brief Summary Text (31):
The barcode reader of the magnetic-resonance instrument of the invention permits the task of entering measurement-sequence specification information into the instrument to be carried out simply, since the task involves only the reading of barcode-encoded data words constituting the specification information by means of the barcode reader. Because of the simplicity by which the measurement-sequence specification information may be entered, the input of the information tends to be free of errors.

Brief Summary Text (32):
The barcode-encoded data words on the measurement-sequence-selection barcode table are preferably labelled to indicate the instructions or data to which the data words correspond. In preferred embodiments of the invention, barcode-encoded data words appropriate to a single type of measurement sequence are grouped together on a single measurement-sequence-selection barcode table. In this way, any danger of a user's intermixing instructions or data appropriate to different types of measurement sequences is reduced. Moreover, the measurement-sequence-selection barcode table preferably includes arrows or other notations indicating the sequence in which the measurement-sequence data words on the barcode table are to be entered.

Brief Summary Text (33):
The measurement-sequence-selection barcode table of the invention is preferably in the form of a paper, cardboard or plastic sheet on which the barcode-encoded data words and associated labels are printed. Preferably, the magnetic-resonance instrument of the invention includes a plotter or other hard-copy display-output device for producing plots or other hard-copy display images of magnetic-resonance data. The instrument controller of the magnetic-resonance instrument is preferably programmed to produce measurement-sequence-selection barcode tables on the plotter or other hard-copy display output device of the instrument. Measurement-sequence-selection barcode tables can be readily reproduced on a photocopy machine.

Brief Summary Text (34):
If desired, several measurement-sequence-selection barcode tables can be bound together to form a booklet. It can be advantageous at certain magnetic-resonance instrument installations to prepare a booklet of measurement-sequence-selection barcode tables tailored for each user of the instrument. The booklet for a particular user would include barcode tables for those magnetic-resonance measurement sequences which the user was qualified or authorized to carry out. For example, a beginning user might not be authorized to perform certain measurement sequences to generate two-dimensional NMR spectra which might require hours of instrument time to complete. In addition, the measurement-sequence control programs specified in the measurement-sequence-selection barcode tables for less experienced users can employ standard values automatically for more of the required parameters, whereas corresponding measurement-sequence control programs specified in the barcode tables for more experienced users can leave it to each user to specify the values for the parameters which he or she deems best for the particular circumstances.

Brief Summary Text (35):
Preferred magnetic-resonance instruments of the invention include a display such as a CRT monitor connected to the instrument controller for displaying messages to the user. Preferably, the instrument controller is programmed to display a message confirming the measurement-sequence data word previously entered from the measurement-sequence-selection barcode table and indicating from which group on the barcode table the next data word is to be read.

Brief Summary Text (36):
In a preferred magnetic-resonance instrument of the invention in the form of a pulse/Fourier-transform spectrometer, an instrument controller embodied as a spectrometer controller includes a computer for exercising control of the functions of the spectrometer by executing spectrometer control programs, including measurement-sequence control programs. Each measurement-sequence control program when it is run specifies a particular NMR measurement sequence, including the sequence of steps to be carried out to excite the NMR signals; to detect, digitize and store the resulting signals; and to process and display the stored data. Measurement-sequence control programs and other spectrometer-control programs can be entered into the computer of the spectrometer controller from a keyboard of a terminal of the spectrometer.

Brief Summary Text (37):
The entry of spectrometer-control programs into the computer of a spectrometer controller of an NMR spectrometer of the invention is preferably restricted to a limited number of persons designated spectrometer managers who are accorded a privileged level of access to the software of the spectrometer controller. The spectrometer managers are identified by a confidential identification code which is encoded in barcode and printed on a card--preferably of pocket size--issued to each spectrometer manager. The barcode-encoded identification code on the card must be read by the barcode reader of the spectrometer and verified by the computer of the spectrometer controller before entry or fundamental alteration of a spectrometer-control program is permitted by the controller. Even after the spectrometer manager has been identified by the barcode-encoded identification code, additional passwords are preferably required to be entered by the manager before a spectrometer control program may be entered or fundamentally altered.

Brief Summary Text (38):
If a card bearing the barcode-encoded identification code of a spectrometer manager were lost or stolen, the spectrometer manager would learn that the card was missing at least by the time he or she attempted to use the spectrometer. In that event the spectrometer manager could initiate cancellation of the identification code printed on the missing card, thereby denying a holder of the lost or stolen card the privileged level of access to the software of the spectrometer controller to which the spectrometer manager was entitled.

Brief Summary Text (39):
In addition, the spectrometer of the invention preferably includes an entry-mode switch at a restricted location within the cabinet of the spectrometer to enable the spectrometer to be set in a spectrometer-control-program entry mode by a service technician or the like who has access to the interior of the cabinet.

Brief Summary Text (40):
For a preferred high-resolution pulse/Fourier-transform NMR spectrometer of the invention, two classes of measurement-sequence specification information are provided by each measurement-sequence control program as the program is run: (I) magnetic-resonance signal excitation and acquisition information, and (II) acquired magnetic-resonance-data processing and output information.

Brief Summary Text (41):
Among the items of magnetic-resonance signal excitation and acquisition information provided for such a spectrometer by preferred measurement-sequence control programs as the programs are run are: (1) the center frequency of a measurement channel, e.g. the approximate magnetic-resonance frequency of protons, carbon-13, or other types of nuclei in the magnetic field of the magnet of the spectrometer, (2) the frequency of the locking channel, e.g. the particular frequency of the proton, deuterium or other nuclear magnetic resonance line from the particular chemical compound used for locking the magnetic field, (3) the width, the intensity, the phase, and the spacing of the radio-frequency pulses applied to the sample from the measurement channel in

each measurement run, e.g. the pulse sequence of the experiment, (4) a flag specifying whether or not a radio-frequency decoupling signal is to the applied to the sample from a decoupling channel, and, if so, the frequency, the power level, and the timing of the decoupling signal, (5) the number of digitized data points to be collected in each measurement run, (6) the time interval between data points, (7) a delay interval between measurement runs, and (8) a flag specifying a termination criterion for the number of measurement runs, e.g. a minimum-signal-to-noise criterion or a fixed-number-of-runs criterion, for which latter criterion the number of runs is also specified. Of the items of excitation and acquisition information listed, the spectrometer of the invention preferably permits the following to be selected by a user reading appropriate barcode-encoded data words from a measurement-sequence-selection barcode table using the barcode reader of the spectrometer: (1) the nucleus to be examined, which determines a center frequency for the measurement channel; (2) the chemical compound used for locking, which determines the frequency of the locking channel; (3) the pulse sequence of the experiment, which identifies the measurement-sequence control program to be executed, which program in turn taking into account the nucleus selected by the user specifies appropriate standard widths, phases, intensities, and spacings for the radio-frequency pulses in the measurement channel, appropriate standard timing for the decoupling signal (if any), an appropriate number of data points, an appropriate spacing between data points, an appropriate delay interval between measurement runs, and a suitable termination criterion for the number of measurement runs; and (4) whether or not a second nucleus is to be decoupled, and, if so, the identity of the second nucleus, which determines whether or not a decoupling signal will be applied, its frequency and an appropriate power level.

Brief Summary Text (42):
Among the items of acquired magnetic-resonance-data processing and output information provided for such a spectrometer by preferred measurement-sequence control programs as the programs are run are: (1) specification of window-function parameters for digital filtering, (2) a flag specifying whether or not resonance peaks are to be integrated, and, if so, specification of the spectral range over which the integration is to be carried out, (3) a flag specifying whether or not to carry out automatic base-line correction, (4) a pointer specifying the media for display or storage of spectral data, and, as appropriate, specification of display parameters, e.g. the pointer may specify that an NMR spectrum be displayed on the CRT monitor of the spectrometer or plotted on the spectrometer plotter with specified scaling, and (5) a flag specifying whether or not spectral peak positions and intensities are to be printed, and, if so, specification of a cut-off intensity value for peak identification. Of the items of acquired data processing and output information listed, the spectrometer of the invention preferably permits the following to be selected by a user reading appropriate barcode-encoded data words from a measurement-sequence-selection barcode table using the barcode reader of the spectrometer: (2) whether or not to integrate resonance peaks, (3) whether or not to carry out automatic base-line correction, (4) selection of display or storage media, and (5) whether or not to print spectral peak positions and intensities. For routine measurement sequences, standard numerical values appropriate for the choices specified by the user are preferably provided automatically by the measurement-sequence control program. Alternatively, the spectrometer-control program can unlock the keyboard of the spectrometer to enable numerical values to be entered by the user.

Brief Summary Text (43):
Another item of measurement-sequence-specification information which can be provided for a pulse/Fourier-transform NMR spectrometer of the invention by a preferred measurement-sequence control program is specification of whether or not the temperature in the probe is to be controlled, and, if so, a desired temperature value. A user may specify that the temperature in the probe is to be controlled by reading a barcode-encoded data word from a measurement-sequence-selection barcode table of the invention. The desired temperature could be entered by way of the keyboard of the spectrometer in the case the spectrometer had a temperature controller, for the probe which was computer controlled, or by way of controls on the temperature controller in the case the spectrometer had a manually-settable temperature controller.

Brief Summary Text (44):
Further items of measurement-sequence specification information which can be provided for a pulse/Fourier-transform NMR spectrometer of the invention by a preferred measurement-sequence control program include identification of replaceable

parts used in the spectrometer, e.g. probes of various frequencies and bore sizes. Preferably, such replaceable parts are labelled with a label bearing a barcode-encoded part-identification code which may be read by the barcode reader of the spectrometer to identify the part.

Brief Summary Text (45):
Preferably, the measurement-selection barcode tables of the invention include barcode-encoded data words which control the progress of the measurement sequences carried out on the magnetic-resonance instrument. For example, barcode-encoded data words are preferably included on the barcode table initiating entry of the measurement-sequence-specification information, instructing the spectrometer to eject any previous sample in the probe, instructing the spectrometer to insert a new sample into the probe, and initiating the measurement sequence itself. The measurement-sequence-selection barcode table preferably includes additional data words to provide for affirmative and negative replies to questions presented on the CRT monitor of the spectrometer. Such questions may inquire as to whether or not a new measurement sequence is to be carried out on the sample presently in the spectrometer, or whether or not a new sample is to be inserted in place of the present sample.

Brief Summary Text (46):
Each measurement-sequence control program is preferably identified by a unique program identifier assigned by the spectrometer manager or other programmer who created the program. Reading one or more barcode-encoded data words from a measurement-sequence-selection barcode table to enter user-specified measurement-sequence specification information preferably causes a master control program running in the spectrometer controller to identify a measurement-sequence control program for the specified measurement sequence, to incorporate in the program a set of excitation and acquisition parameters and acquired-data processing and output parameters either directly specified by the barcode-encoded data words entered by the user or automatically selected taking into account the data words entered by the user, and to execute the program.

Brief Summary Text (47):
A magnetic-resonance instrument of the invention in the form of a magnetic-resonance tomographic imaging device preferably has an instrument controller which is programmed to permit only persons who enter a valid barcode-encoded identification code via the barcode reader of the device to operate the device. Each qualified operator of the tomographic imaging device is preferably issued a card--preferably of pocket size--bearing such a barcode-encoded identification code which identifies the operator. Access to a magnet room in which the magnet of the tomographic imaging device is located is preferably controlled by the instrument controller of the device by means of a remote-controlled lock on each door to the magnet room. In this way access to the magnet room can be limited to persons who enter a valid barcode-encoded identification code into the instrument-controller of the magnetic-resonance tomographic imaging device. A magnet-room-access auxiliary barcode reader located close to a door to the magnet room and connected to the instrument controller may facilitate the reading of the identification codes of persons who wish to enter the magnet room.

Brief Summary Text (48):
Preferably, each patient examined by the magnetic-resonance tomographic imaging device of the invention is assigned a unique barcode-encoded patient-identification code. The doctor in charge of the tomographic-imaging examination is also preferably assigned a unique barcode-encoded doctor-identification code. Both the patient identification code and the doctor-identification code in barcoded form are preferably taken with the patient to the magnet room and read immediately prior to the examination to confirm the identity of the patient. For this purpose, the barcode-encoded patient identification code of the patient and the doctor-identification code of his or her doctor is preferably printed on a nonmagnetic wristband worn by the patient during the examination. The instrument controller for the magnetic-resonance imaging device is preferably programmed not to allow the examination to proceed until the identity of the patient is established by reading of the barcode-encoded patient and doctor-identification codes. Preferably, a magnet-room auxiliary barcode reader connected to the instrument controller is located in the magnet room and may be used to read the barcode-encoded patient and doctor identification codes of the patient. The patient and doctor identification codes are preferably printed on each tomographic image taken of the patient for purposes of identification, as well as on any printout of data pertaining to the

examination produced by the tomographic imaging device.

Brief Summary Text (49):
Preferably, the magnetic-resonance tomographic imaging device of the invention permits an operator to specify the following items of measurement-sequence specification information by reading selected barcode-encoded measurement-sequence data words from one or more measurement-sequence-selection barcode tables using the barcode reader of the device: (1) the body part to be imaged, e.g. head, torso, leg; (2) the type of image, which determines the tomographic-imaging pulse and magnetic-gradient sequence to be applied; (3) the number and spacing of the slices to be imaged; (4) a flag specifying whether or not to activate automatic radio-frequency tuning; (5) a flag specifying whether or not to activate automatic magnetic-field shimming; and (6) identification of replaceable parts employed in the tomographic imaging device, e.g. replaceable probe coupling circuits such as surface coils of various conformations and bird-cage resonators of various forms and capacities. In connection with the identification of replaceable parts employed in the device, it is preferred that each such replaceable part be labelled with a barcode-encoded part-identification code. The presence of the part in the tomographic imaging device could then be verified by reading the part-identification code of the part in the device with the magnet-room auxiliary barcode reader. The instrument controller of the device is preferably programmed not to permit the examination to proceed until the identity of the replaceable parts is confirmed by reading the part-identification codes labelling such parts in the device. The instrument controller can verify that each of the replaceable parts present in the device has an adequate power rating and is otherwise suitable for the tomographic imaging measurement sequence specified.

Brief Summary Text (50):
In addition, the progress of a tomographic examination is preferably controlled in a magnetic-resonance tomographic imaging device of the invention by reading of barcode-encoded data words from a measurement-sequence-selection barcode table. Barcode-encoded data words selected by an operator could cause the device to advance to the next step of the measurement sequence, hold the present state of the device to the extent that it is safe to do so, escape from barcode control, and abort the imaging process.

Brief Summary Text (51):
Preferred magnetic-resonance instruments of the invention are flexible in that new measurement-sequence control programs may be written to specify new magnetic-resonance measurement sequences which users desire to run on the instrument. Each such new measurement-sequence control program can be assigned a control-program identifier which is identified by measurement-sequence specification information from one or more barcode-encoded measurement-sequence data words. Thereafter, users can carry out the new measurement sequence by entering the appropriate barcode-encoded measurement-sequence data word or words by way of the barcode reader of the instrument.

Brief Summary Text (52):
Advantageously, preferred magnetic-resonance instruments of the invention may be operated by persons who have no knowledge of the software needed to control the instrument. The specification of measurement sequences can proceed quickly. For example, only four barcode-encoded data words need to be entered to select and begin a routine NMR measurement sequence in one preferred pulse/Fourier-transform spectrometer of the invention.

Drawing Description Text (3):
FIG. 1 shows a schematic block-diagram of a preferred NMR spectrometer of the invention.

Detailed Description Text (2):
Turning now to FIG. 1, an NMR spectrometer 1 comprises a magnet system providing an essentially homogeneous magnetic field in which a probe head is positioned. The magnetic system and the probe head are identified collectively in FIG. 1 as magnet and probe head unit 11. A radio-frequency transmitter 13 and a receiver 15 are connected to the probe head of unit 11.

Detailed Description Text (3):
A pulse programmer 17 is connected to the radio-frequency transmitter 13 in order to control the sequences of radio-frequency pulses produced by the transmitter 13 and

applied to the probe head. A data processor 19 is connected to an output of the receiver 15. The data processor 19 is capable of accumulating and storing magnetic-resonance signals detected and digitized by the receiver 15 and digitally processing the stored digitized signals for analysis and display.

Detailed Description Text (4):
An automatic sample changer 21 is connected to the probe head in the magnet and probe head unit 11. The automatic sample changer 21 is adapted to store up to about 120 NMR sample tubes in a generally circular sample-holder carousel and to rotate the carousel stepwise to position a selected sample tube in the carousel at a sample-tube take-off/return position. The automatic sample changer is further adapted to withdraw a sample tube located at the take-off/return position, then to insert the sample tube into the probe head for measurement, and, after the measurement is completed, to remove the sample tube from the probe head and replace it in the sample-holder carousel of the sample changer at the take-off/return position. Each sample tube can have a generally-cylindrical label collar mounted axially on it to which an adhesive label may be affixed. A barcode-encoded sample-identification code can be printed on the label to identify the sample. The automatic sample changer 21 includes a sample-tube-label barcode reader mounted in a position to read barcode-encoded sample-identification codes on the sample tubes having-collars with labels bearing such codes.

Detailed Description Text (5):
The pulse programmer 17, the data processor 19, the automatic sample changer 21, and the sample-tube-label barcode reader are connected to a spectrometer controller housed in a terminal 23. The spectrometer controller includes a digital computer having read/write storage and a magnetic-disk storage unit for storing spectrometer control programs for controlling the pulse programmer 17, the data processor 19 and the automatic sample changer 21. The terminal 23 comprises a keyboard 27 and a CRT monitor 29 for data display. A hand-holdable barcode-reader wand 31 is connected to the terminal 23 by a flexible signal-transmission cable 33. Positioned adjacent to the keyboard 27 is a control panel 25 on which a measurement-sequence-selection barcode table 35 is removably mounted. FIG. 2 illustrates in greater detail a preferred measurement-sequence-selection barcode table 135 for a manual operating mode of the spectrometer.

Detailed Description Text (6):
Turning now to FIG. 2, the measurement-sequence-selection barcode table 135 is a cardboard sheet having a corner cutout 137 and a keyrow cutout 139. The keyrow cutout 139 is dimensioned so that a top row of keys of the keyboard 27 fits through the cutout to hold the barcode table in place. The corner cutout 137 provides clearance for certain indicator lights (not shown) mounted in the control panel 25 of the terminal 23 to be seen with the barcode table 135 in place.

Detailed Description Text (7):
The measurement-sequence-selection barcode table 135 has 38 barcode-encoded data Words printed on an upper surface of the table. The 38 barcode-encoded data words are arranged in five groups. An experiment-initiation group 150 includes a first data word 152 labelled "Start Experiment" and a second data word 154 labelled "Insert Sample." A user-identification group 156 includes eight barcode-encoded data words labelled "User 1" through "User 8," respectively. Positioned below the user-identification group 156 of data words is an experiment/solvent group 160 of 25 barcode-encoded data words arranged in a five-by-five array. The five rows of the array are labelled with the following five solvents which are commonly used to dissolve samples in high-resolution NMR experiments and which have resonance lines suitable for locking the magnetic field: acetone, benzene, CDCl.sub.3, D.sub.2 O and DMSO. The five columns of the experiment/solvent group 160 are labelled with the following five labels: ".sup.1 H," ".sup.1 H S/N ABORT," ".sup.13 C," "13C S/N ABORT," and ".sup.13 C Multiplicity Analysis." To the right of the experiment/solvent 160 of data words is a Yes/No group 172 of data words, consisting of a data word 174 labelled "Yes" and a data word 176 labelled "No." Finally, an inject group containing a single barcode-encoded data word 178 labelled "Inject" is located below the Yes/No group 172 of data words. As may be seen in FIG. 2, arrows are drawn on the barcode table 135 from the experiment-initiation group 150 to the user-identification group 156, from the user-identification group 156 to the experiment/solvent group 160, from the experiment/solvent group 160 to the Yes/No group 162, and from the Yes/No group 172 to the inject group 178.

Detailed Description Text (8):

In operation, a master control program executed by the computer of the spectrometer controller provides supervisory control of the operation of the spectrometer. The master control program controls the input of spectrometer control information into the spectrometer controller from both the keyboard 27 and the barcode reader 31. The master control program distinguishes between ordinary users and spectrometer managers. A spectrometer manager is recognized by the spectrometer controller running the master control program by an identification code unique to the manager entered by way of the barcode reader.

Detailed Description Text (9):
A spectrometer manager, once so identified, can instruct the master control program to place the spectrometer in a number of operating modes. A master-control-instruction barcode table has barcode-encoded data words printed on it which can be entered into the spectrometer controller by a spectrometer manager using the barcode-reader wand 31 to specify the various operating modes. One such operating mode is a restricted barcode-encoded information entry mode. With the spectrometer in the restricted barcode-encoded information entry mode, the keyboard 27 of the spectrometer is effectively locked and users can enter spectrometer-control information into the spectrometer controller--with limited exceptions--only by way of the barcode reader 31. Another operating mode which can be specified by a spectrometer manager is a manual-sample-insertion operating mode or an automatic-sample-changer operating mode.

Detailed Description Text (10):
In operation, with the spectrometer in the manual-sample-insertion operating mode and in the restricted barcode-encoded information entry mode, a user enters barcode-encoded data words into the spectrometer controller by gently moving the barcode-reader wand 31 over a selected data word on the measurement-sequence-selection barcode table 135. Entry of the "Start Experiment" data word 152 from the experiment-initiation group 150 on the barcode table 135 initiates the sequence of an experiment by turning on the sample-lift air jet of the probe. A message is then displayed on the CRT monitor 29 to exchange or insert a sample tube. The user inserts a sample tube in a sample-insertion port and then enters the "Insert-Sample" data word 154 of the experiment-initiation group 150 by using the barcode-reader wand 31. Entry of the "Insert-Sample" data word 154 causes the sample-lift air jet to terminate and the sample tube to settle into the probe in the magnet. A message is then displayed on the monitor 29 instructing the user to enter a user code. The user then enters one of the eight user-identification data words in the user identification group 156. The user-identification code thus selected is employed to identify all data collected in the measurement sequence.

Detailed Description Text (11):
After the user-identification code is entered, a message is displayed on the monitor instructing the user to enter an experiment/solvent combination. The user selects a desired experiment corresponding to one of five columns of the experiment/solvent group 160 on the measurement-sequence-selection barcode table 135. In addition, the user identifies which of the five solvents associated with the rows of the experiment/solvent group 160 was used as a solvent for the sample in the sample tube. If the desired experiment and solvent combination is not found on the measurement-sequence-selection barcode table 135, the user must choose another barcode table which includes the desired combination. Reading the barcode-encoded data word corresponding to the column of the desired experiment and the row of the solvent with the barcode-reader wand enters an experiment/solvent combination into the spectrometer controller. A message is then displayed on the CRT monitor 29 requesting an optional plot title. The keyboard is unlocked to permit the user to input a title if desired. The spectrometer controller then recalls and executes an appropriate measurement-sequence control program to carry out the desired measurement. All parameters required for the measurement sequence are automatically set to standard values, and data acquisition and processing is started. In particular, the measurement-sequence-control program automatically takes care of shimming the magnet, rotating the sample tube, locking the magnetic field to the specified solvent line, adjusting the receiver gain, selecting an appropriate criterion for determining the number of measurement runs, accumulating and Fourier-transforming or otherwise processing the data optimizing the spectral width in the case of two-dimensional experiments, carrying out carbon multiplicity analysis automatically should that experiment have been selected, plotting spectra with integrals and automatic expansion, and optimizing the plots of two-dimensional spectra.

Detailed Description Text (12):
When the measurement sequence is finished, the CRT monitor 29 displays a message asking whether another experiment with the same sample is desired. The user answers the question by reading with the barcode-reader wand 31 either the Yes data word 174 or the No data word 176 in the Yes/No group of data words 172. If the Yes data word 174 is selected, a message to enter a desired experiment/solvent combination is displayed on the monitor 29 and the procedure continues as explained above.

Detailed Description Text (13):
If the No data word 176 is read with the barcode reader wand 31, the monitor displays a message asking if the user wishes to perform an experiment on a different sample. The user must again respond to the question by selecting one of the Yes and No data words in the Yes/No group 172.

Detailed Description Text (14):
If the user responds by selecting the Yes barcode-encoded data word 174, the sample-lift air jet is actuated and the previous sample tube in the probe is raised to the sample-insertion port. A message is then displayed requesting that the samples be exchanged. After the user exchanges the samples by removing the previous sample tube from the sample-insertion port and replacing it with a new sample tube, the injection data word 178 is read, which causes the sample-lift air jet to be turned off and the new sample tube to settle into the probe. The CRT monitor 29 then displays a message requesting selection of an experiment/solvent combination and the procedure continues as explained above.

Detailed Description Text (15):
If the user responds by selecting the NO barcode-encoded data word 176, the sample tube in the probe is raised to the sample-insertion port with the sample-lift air jet. A message on the CRT monitor asks the user remove the sample from the sample-insertion port and to turn off the sample-lift air jet by entering the injection data word 178. The spectrometer is then free for use by others.

Detailed Description Text (16):
When the spectrometer is in the restricted barcode-encoded information entry mode and the automatic-sample-changer operating mode, a measurement-sequence-specification barcode table is used which is generally similar to the barcode table 135 illustrated in FIG. 2, but in which certain of the barcode-encoded data words and their associated labels on the table are different. When the spectrometer is placed in the automatic-sample-changer operating mode, the monitor 29 initially displays the message "User Identification." The spectrometer is free for use by ordinary users as well as spectrometer managers. A user enters one of eight barcode-encoded data words from a user-identification group of data words on the barcode table using the barcode-reader wand 31.

Detailed Description Text (17):
After entry of the user-identification code, the monitor 29 displays the message "Free for Input, Sample Identification." As noted above, the automatic sample changer 21 includes a sample-tube-label barcode reader positioned to read labels affixed to label collars mounted on sample tubes, which labels bear barcode-encoded sample-identification codes. The user enters a sample identification code by reading the barcode on the label of the sample tube using the hand-holdable barcode-reader wand 31.

Detailed Description Text (18):
After the sample identification code is read, the monitor displays the message "Experiment/Solvent." The measurement-sequence-selection barcode table for the automatic-sample-changer operating mode includes an experiment/solvent group of twenty-five barcode-encoded data words arranged in a 5.times.5 array generally similar to the experiment/solvent group 160 of the barcode table 135 of FIG. 2. By reading one of the barcode-encoded data words in the 5.times.5 array, the user specifies one of five experiments to be run on the sample and one of five solvents in which the sample is dissolved and which can provide a resonance signal for the locking channel.

Detailed Description Text (19):
After the experiment/solvent combination is selected, the RT monitor 29 of the spectrometer displays the message "Put Sample in Sample Holder, Verify by Entering Sample in Holder, Barcode." At this point, the user inserts the sample tube in the sample-holder carousel of the automatic sample changer and then reads a

barcode-encoded data word on the measurement-sequence-selection barcode table which is labeled "Sample in Holder" to verify that the sample tube has been placed in the sample-holder carousel.

Detailed Description Text (20):
The spectrometer then begins automatic background measurement operation; specifically, the spectrometer begins the measurement sequence for any samples to be measured in the automatic sample changer as a background measurement operation, while essentially simultaneously permitting users to enter measurement-sequence-specification information data for additional samples as a foreground data-entry operation. The master control program of the spectrometer controller begins the automatic background measurement operation by turning on the sample-lift air jet to eject any sample tube presently located in the probe and to transfer the sample tube to the sample-holder carousel of the automatic sample changer. The sample changer then advances the sample-holder carousel one position and the barcode-encoded sample-identification code on the sample-tube label of the next sample tube in the carousel, if any, is read. If the sample-tube-label identifies the sample as one which is to be measured, the spectrometer controller causes the automatic sample changer to transfer the sample tube to the sample-insertion port and to lower the sample tube into the probe. If the sample is not one which has been previously specified to be measured, or if there is no sample in that location in the sample-holder carousel, or if the sample is one which has already been measured, the spectrometer controller causes the automatic sample changer to advance the sample-holder carousel an additional position. The barcode-encoded sample-identification code on the sample-tube label of the sample in the next position, if any, is then read and the cycle repeats.

Detailed Description Text (21):
Once a sample tube has been loaded into the probe, the spectrometer control program specified by the experiment/solvent combination entered for the sample is carried out. The data obtained from the measurement is stored under the user identification code of the user who entered the measurement-sequence-specification information for that sample. When the measurement is completed, the sample-lift air jet is turned on, the sample ejected and the process repeated for the next sample in the sample changer.

Detailed Description Text (22):
During the automatic background measurement operation, users may identify additional new samples in the foreground by first entering a barcode-encoded user-identification code, then reading the barcode-encoded sample-identification code on the sample-tube-label of each additional sample and finally reading a barcode-encoded data word specifying an experiment/solvent combination for the sample so identified. The sample tubes containing the additional samples may be placed at random positions in the sample-holder carousel. The automatic sample changer advances the carousel stepwise and all identified samples which have not previously been measured are measured as they reach the measurement position. Samples which have previously been measured or which have not been identified to the spectrometer controller by reading of their barcode-encoded sample-identification labels and entering an associated experiment/solvent combination are ignored.

Detailed Description Text (23):
The presence of a label collar and sample-tube-label on a sample tube can occasionally introduce a slight imbalance which causes the tube to wobble slightly as it spins in the probe. In certain circumstances such wobbling can introduce small spinning sidebands which usually are no greater than background noise and can be ignored, but which occasionally represent a problem in certain NMR experiments requiring extremely high resolution. In the present preferred spectrometer of the invention, such spinning sidebands can be avoided even with the spectrometer in the automatic-sample-changer operating mode. Specifically, a user can cause the automatic sample changer to hold a sample tube which does not carry a label collar in the sample-holder carousel at the take-off/return position. The user can bypass the barcode reader of the automatic sample changer and read a barcode-encoded sample-identification code for the sample with the hand-holdable barcode reader wand of the spectrometer. The spectrometer and automatic sample changer then process the sample tube without the label collar just as if the sample-identification code had been read from a label collar with the barcode reader of the automated sample changer.

Detailed Description Text (24):

A listing of a barcode-reader interface subroutine for a master control program for a preferred pulse/Fourier-transform NMR spectrometer of the invention written in the Pascal programming language for an "Aspect 3000" digital computer is attached hereto as Appendix A and made a part of this specification.

Detailed Description Text (25):
It is not intended to limit the present invention to the specific embodiments described above. It is recognized that changes may be made in the magnetic-resonance instrument described herein without departing from the scope and teaching of the instant invention and it is intended to encompass all embodiments, alterations and modifications consistent with the invention. ##SPC1##

Other Reference Publication (1):
K. Roth, NMR-Tomographie und-Spektroskopie in der Medizin, Eine Einfuhrung, Springer-Verlag, 1984.

CLAIMS:

1. A magnetic-resonance instrument programmable to perform a plurality of magnetic-resonance measurement sequences, comprising:

(a) a magnet for generating a magnetic field;

(b) a probe having radio-frequency coupling circuitry positionable in the magnet for coupling radio-frequency signals between the coupling circuitry and test matter to be analyzed in the magnetic field;

(c) a radio-frequency generator/transmitter connected to the coupling circuitry of the probe for generating and amplifying radio-frequency excitation signals in accordance with a magnetic-resonance measurement sequence for exciting magnetic-resonance signals from the test matter in the probe, the timing of the excitation signals being specified by control signals applied to the generator/transmitter;

(d) a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe for amplifying and detecting magnetic-resonance signals from the test matter and digitizing the signals to form digitized magnetic-resonance signals;

(e) a digitized-signal averager/processor connected to the receiver/digitizer for accumulating and storing digitized magnetic-resonance signals from the receiver/digitizer and digitally processing the stored signals for interpretation and display, processing operations carrier out by the averager/processor being specified by control signals applied to the averager/processor;

(f) a programmable instrument controller having measurement-sequence control-program storage for storing a plurality of measurement-sequence control programs, each measurement-sequence control program specifying one of the plurality of magnetic-resonance measurement sequences which the magnetic-resonance instrument is programmable to perform and being associated with a digital control-program identifier for identifying the measurement-sequence control program, the instrument controller being adapted to recall and execute selectively a measurement-sequence control program identified by a specified control-program identifier to generate control signals for the magnetic-resonance measurement sequence specified by the control program, the instrument controller being connected to the radio-frequency generator/transmitter for applying control signals to the generator/transmitter to specify the timing of the radio-frequency excitation signals generated by the generator/transmitter and connected to the digitized-signal averager/processor for applying control signals to the averager/processor to specify processing operation carried out by the averager/processor;

(g) a barcode reader connected to the instrument controller for reading barcode-encoded data words and transmitting signals representative of the data words to the instrument controller, a plurality of barcode-encoded data words defining measurement-sequence data words, one or more barcode-encoded data words being associated with each of the magnetic-resonance measurement sequences which the magnetic-resonance instrument is programmable to perform to constitute measurement-sequence specification information sufficient to specify the measurement sequence at least to the extent of permitting the control-program identifier associated with a measurement-sequence control program which specifies the

measurement sequence to be identified, the instrument controller being adapted to receive signals from the barcode reader representative of the one or more barcode-encoded measurement sequence data words which constitute measurement-sequence specification information specifying a measurement sequence and to recall and execute the measurement-sequence control program identified by the control-program identifier identified in the measurement-sequence specification information; and

(h) at least one measurement-sequence-selection barcode table having a plurality of barcode-encoded measurement-sequence data words arranged on it, each barcode-encoded measurement-sequence data word on the barcode table being selectively readable by a user with the barcode reader to transmit signals to the instrument controller representative of the measurement-sequence data word, the measurement-sequence-selection barcode table having a plurality of measurement sequences associated with it which the magnetic-resonance instrument is programmable to perform, each of the measurement sequences associated with the barcode table being specifiable by magnetic-sequence specification information constituted by one or more of the barcode-encoded measurement-sequence data words included on the barcode table, so that a user can cause the magnetic-resonance instrument to selectively perform a magnetic-resonance measurement sequence specified by one of the measurement-sequence control programs associated with the measurement-sequence selection barcode table by reading a corresponding one or more of the barcode-encoded measurement-sequence data words on the measurement-sequence-selection barcode table with the barcode reader.

2. The magnetic-resonance instrument according to claim 1 in which the barcode reader is a hand-holdable barcode-reader wand connected to the instrument controller by means of a flexible signal-transmission cable.

3. The magnetic-resonance instrument according to claim 2 in which the magnetic-resonance instrument includes a console having a control panel, the barcode-reader wand being connected to the console by the signal-transmission cable and the measurement-sequence-selection barcode table being removable mountable on the control panel at a location where the barcode-encoded measurement-sequence data words arranged on the barcode table may be read by the barcode reader wand.

4. The magnetic-resonance instrument according to claim 3 in which the coupling circuitry of the probe comprises a replaceable element, the replaceable element being labelled with a barcode-encoded part-identification code for identifying the element, the instrument controller being adapted to receive signals from a barcode reader representative of the part-identification code and to condition performance of a measurement sequence upon verification that the signals represent a replaceable element acceptable for the measurement sequence.

5. The magnetic-resonance instrument according to claim 3 in which the instrument is a pulse/Fourier-transform NMR spectrometer.

6. The magnetic-resonance instrument according to claim 3 in which the instrument is a magnetic-resonance tomographic imaging device.

7. A magnetic-resonance spectrometer programmable to perform a plurality of magnetic-resonance measurement sequences, comprising:

(a) a magnet for generating a substantially homogeneous magnetic field;

(b) a probe having radio-frequency coupling circuitry positionable in the magnet for positioning a sample to be analyzed in the magnetic field and for coupling radio-frequency signals between the sample and the coupling circuitry;

(c) a radio-frequency generator/transmitter connected to the coupling circuitry of the probe for generating and amplifying radio-frequency excitation signals in accordance with a magnetic-resonance measurement sequence for exciting magnetic-resonance signals from the sample in the probe, the timing of the excitation signals being specified by control signals applied to the generator/transmitter;

(d) a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe for amplifying and detecting magnetic-resonance signals from the sample to be analyzed in the magnetic field and for coupling radio-frequency signals between the

sample and the coupling circuitry;

(c) a radio-frequency generator/transmitter connected to the coupling circuitry of the probe for generating and amplifying radio-frequency excitation signals in accordance with a magnetic-resonance measurement sequence for exciting magnetic-resonance signals from the sample in the probe, the timing of the excitation signals being specified by control signals applied to the generator/transmitter;

(d) a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe for amplifying and detecting magnetic-resonance signals from the sample and digitizing the signals to form digitized magnetic-resonance signals;

(e) a digitized-signal averager/processor connected to the receiver/digitizer for accumulating and storing digitized magnetic-resonance signals from the receiver/digitizer and digitally processing the stored signals for interpretation and display, processing operations carried out by the averager/processor being specified by control signals applied to the averager/processor;

(f) a programmable spectrometer controller having measurement-sequence control-program storage for storing a plurality of measurement-sequence control programs, each measurement-sequence control program specifying one of the plurality of magnetic-resonance measurement sequences which the spectrometer is programmable to perform and being associated with a digital control-program identifier for identifying the measurement-sequence control program, the spectrometer controller being adapted to recall and execute selectively a measurement-sequence control program identified by a specified control-program identifier to generate control signals for the magnetic-resonance measurement sequence specified by the control program, the spectrometer controller being connected to the radio-frequency generator/transmitter for applying control signals to the generator/transmitter to specify the timing of the radio-frequency excitation signals generated by the generator/transmitter and connected to the digitized-signal averager/processor for applying control signals to the averager/processor to specify processing operations carried out by the averager/processor;

(g) a barcode reader connected to the spectrometer controller for reading barcode-encoded data words and transmitting signals representative of the data words to the spectrometer controller, a plurality of barcode-encoded data words defining measurement-sequence data words, one or more barcode-encoded data words being associated with each of the magnetic-resonance measurement sequences which the spectrometer is programmable to perform to constitute measurement-sequence specification information sufficient to specify the measurement sequence at least to the extent of permitting the control-program identifier associated with a measurement-sequence control program which specifies the measurement sequence to be identified, the spectrometer controller being adapted to receive signals from the barcode reader representative of the one or more barcode-encoded measurement sequence data words which constitute measurement-sequence specification information specifying a measurement sequence and to recall and execute the measurement-sequence control program identified by the control-program identifier identified in the measurement-sequence specification information; and

(h) at least one measurement-sequence-selection barcode table having a plurality of barcode-encoded measurement-sequence data words arranged on it, each barcode-encoded measurement-sequence data word on the barcode table being selectively readable by a user with the barcode reader to transmit signals to the spectrometer controller representative of the measurement-sequence data word, the measurement-sequence-selection barcode table having a plurality of measurement sequences associated with it which the spectrometer is programmable to perform, each of the measurement sequences associated with the barcode table being specifiable by magnetic-sequence specification information constituted by one or more of the barcode-encoded measurement-sequence data words included on the barcode table, so that a user can cause the spectrometer to selectively perform a magnetic-resonance measurement sequence specified by one of the measurement-sequence control programs associated with the measurement-sequence selection barcode table by reading a corresponding one or more of the barcode-encoded measurement-sequence data words on the measurement-sequence-selection barcode table with the barcode reader.

8. The magnetic-resonance spectrometer according to claim 7 in which the barcode reader is a hand-holdable barcode-reader wand connected to the instrument controller

by means of a flexible signal-transmission cable.

9. The magnetic-resonance spectrometer according to claim 8 in which the magnetic-resonance spectrometer includes a console having a control panel, the barcode-reader wand being connected to the console by the signal-transmission cable and the measurement-sequence-selection barcode table being removably mountable on the control panel at a location where the barcode-encoded measurement-sequence data words arranged on the barcode table may be read by the barcode reader wand.

10. The magnetic-resonance spectrometer according to claim 9 in which the instrument is a pulse/Fourier-transform NMR spectrometer.

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Search Results - Record(s) 1 through 1 of 1 returned.

☐ 1. Document ID: US 5041789 A

L30: Entry 1 of 1 File: USPT Aug 20, 1991

US-PAT-NO: 5041789
DOCUMENT-IDENTIFIER: US 5041789 A

TITLE: Magnetic-resonance instrument employing barcode experiment specification

DATE-ISSUED: August 20, 1991

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Keller; Tony	Reinstetten-Forchheim			DE
Laukien; Gunther R.	Rheinstetten			DE
Spraul; Manfred	Ettlingen			DE

US-CL-CURRENT: 324/318; 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

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Term	Documents
REAL.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	275669
REALS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	123
TIMING.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	502264
TIMINGS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	30545
DELIVER$4	0
DELIVER.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	223387
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DELIVERABLY.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	49
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Previous Page Next Page

Search Results - Record(s) 1 through 8 of 8 returned.

☐ 1. Document ID: US 20020115941 A1

L33: Entry 1 of 8 File: PGPB Aug 22, 2002

PGPUB-DOCUMENT-NUMBER: 20020115941
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020115941 A1

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in interior body regions

PUBLICATION-DATE: August 22, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Whayne, James G.	Saratoga	CA	US	
Swanson, David K.	Mountain View	CA	US	
Panescu, Dorin	Sunnyvale	CA	US	
Dupree, Daniel A.	Saratoga	CA	US	

US-CL-CURRENT: 600/523; 600/374, 702/68, 707/102

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

☐ 2. Document ID: US 20010044585 A1

L33: Entry 2 of 8 File: PGPB Nov 22, 2001

PGPUB-DOCUMENT-NUMBER: 20010044585
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20010044585 A1

TITLE: Interactive systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions

PUBLICATION-DATE: November 22, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Dupree, Daniel A.	Saratoga	CA	US	
Nguyen, Tuan	Austin	TX	US	
Panescu, Dorin	San Jose	CA	US	
Whayne, James G.	San Jose	CA	US	
McGee, David	Sunnyvale	CA	US	
Swanson, David K.	Campbell	CA	US	

US-CL-CURRENT: 600/509

☐ 3. Document ID: US 6389311 B1

L33: Entry 3 of 8 File: USPT May 14, 2002

US-PAT-NO: 6389311
DOCUMENT-IDENTIFIER: US 6389311 B1

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in interior body regions

DATE-ISSUED: May 14, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Whayne; James G.	Saratoga	CA		
Swanson; David K.	Mountain View	CA		
Panescu; Dorin	Sunnyvale	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/523

☐ 4. Document ID: US 6289239 B1

L33: Entry 4 of 8 File: USPT Sep 11, 2001

US-PAT-NO: 6289239
DOCUMENT-IDENTIFIER: US 6289239 B1

TITLE: Interactive systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions

DATE-ISSUED: September 11, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Panescu; Dorin	Sunnyvale	CA		
McGee; David	Sunnyvale	CA		
Whayne; James G.	Saratoga	CA		
Burnside; Robert R.	Mountain View	CA		
Swanson; David K.	Mountain View	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/523

☐ 5. Document ID: US 6192266 B1

L33: Entry 5 of 8 File: USPT Feb 20, 2001

US-PAT-NO: 6192266
DOCUMENT-IDENTIFIER: US 6192266 B1

TITLE: Systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions using real and idealized images

DATE-ISSUED: February 20, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Dupree; Daniel A.	Saratoga	CA		
Nguyen; Tuan	San Jose	CA		
Panescu; Dorin	Sunnyvale	CA		
Whayne; James G.	Saratoga	CA		

US-CL-CURRENT: 600/427; 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

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☐ 6. Document ID: US 6115626 A

L33: Entry 6 of 8 File: USPT Sep 5, 2000

US-PAT-NO: 6115626
DOCUMENT-IDENTIFIER: US 6115626 A

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in instruments in interior body regions

DATE-ISSUED: September 5, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Whayne; James G.	Saratoga	CA		
Swanson; David K.	Mountain View	CA		
Panescu; Dorin	Sunnyvale	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/427; 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

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☐ 7. Document ID: US 6106460 A

L33: Entry 7 of 8 File: USPT Aug 22, 2000

US-PAT-NO: 6106460
DOCUMENT-IDENTIFIER: US 6106460 A

TITLE: Interface for controlling the display of images of diagnostic or therapeutic instruments in interior body regions and related data

DATE-ISSUED: August 22, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Panescu; Dorin	Sunnyvale	CA		
McGee; David	Sunnyvale	CA		
Whayne; James G.	Saratoga	CA		
Burnside; Robert R.	Mountain View	CA		
Swanson; David K.	Mountain View	CA		
Dupree; Daniel A.	Saratoga	CA		

US-CL-CURRENT: 600/300

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 8. Document ID: US 6014581 A

L33: Entry 8 of 8 File: USPT Jan 11, 2000

US-PAT-NO: 6014581
DOCUMENT-IDENTIFIER: US 6014581 A

TITLE: Interface for performing a diagnostic or therapeutic procedure on heart tissue with an electrode structure

DATE-ISSUED: January 11, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Whayne; James G.	Saratoga	CA		
Panescu; Dorin	Sunnyvale	CA		
McGee; David	Sunnyvale	CA		
Dupree; Daniel A.	Saratoga	CA		
Swanson; David K.	Mountain View	CA		
Nguyen; Tuan	San Jose	CA		

US-CL-CURRENT: 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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Term	Documents
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SEQUENCES.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	180940
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DISPLAYABIE.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	2
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Previous Page Next Page

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☑ 1. Document ID: US 5465361 A

L34: Entry 1 of 1 File: USPT Nov 7, 1995

US-PAT-NO: 5465361
DOCUMENT-IDENTIFIER: US 5465361 A

TITLE: Microcode linker/loader that generates microcode sequences for MRI sequencer by modifying previously generated microcode sequences

DATE-ISSUED: November 7, 1995

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hoenninger, III; John C.	Oakland	CA		

US-CL-CURRENT: 717/168; 324/309, 324/312

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

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Term	Documents
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(L12 AND (DISPLAY$4 WITH PULSE WITH SEQUENCE)).USPT,PGPB,JPAB,EPAB,DWPI,TDBD.	1

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Previous Page Next Page

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L30: Entry 1 of 1 File: USPT Aug 20, 1991

DOCUMENT-IDENTIFIER: US 5041789 A
TITLE: Magnetic-resonance instrument employing barcode experiment specification

Abstract Text (1):
A multi-experiment magnetic-resonance instrument such as a programmable pulse/Fourier-transform nuclear-magnetic-resonance ("NMR") spectrometer, an electron-paramagnetic-resonance spectrometer, or a magnetic resonance tomographic imaging device, capable of performing any one of a plurality of magnetic-resonance measurement sequences selected by a user and comprising: a magnet for generating a magnetic field; a probe having radio-frequency coupling circuitry positionable in the magnet; a radio-frequency generator/transmitter connected to the coupling circuitry of the probe; a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe; a digitized-signal averager/processor connected to the receiver/digitizer; a programmable instrument controller having measurement-sequence control-program storage; a barcode reader connected to the instrument controller; and at least one measurement-sequence-selection barcode table having a plurality of barcode-encoded measurement-sequence data words arranged on it.

Brief Summary Text (2):
The present invention concerns a multi-experiment magnetic-resonance instrument--such as a programmable pulse/Fourier-transform nuclear-magnetic-resonance ("NMR") spectrometer--capable of performing any one of a plurality of magnetic-resonance measurement sequences selected by a user. As used herein, the term "magnetic-resonance instrument" includes, for example, NMR spectrometers, electron-paramagnetic-resonance spectrometers, or magnetic-resonance tomographic imaging devices.

Brief Summary Text (4):
Conventional pulse/Fourier-transform NMR spectrometers are generally capable of performing a wide variety of magnetic-resonance measurement sequences. Such magnetic-resonance measurement sequences typically involve subjecting a sample in a magnetic field to pulsed or otherwise time-varying radio-frequency fields at one or more frequencies; amplifying, detecting, and digitizing the magnetic-resonance signals elicited from the sample by the radio-frequency fields; and processing the resulting digitized signals by Fourier transformation or other data processing operations for analysis and display. As used herein, the term "magnetic-resonance measurement sequence" can refer to sequences in which two or more operations in a magnetic resonance experiment which are carried out simultaneously--such as, for example, simultaneous irradiation of a sample at two frequencies--as well as operations which follow one another in time.

Brief Summary Text (5):
A conventional pulse/Fourier-transform NMR spectrometer ordinarily includes a radio-frequency pulse-generator/transmitter and a pulse programmer for controlling the pulse-generator/transmitter to produce sequences of radio-frequency excitation pulses. In general, each pulse in such a pulse sequence has a well-defined shape, intensity, duration, phase, and separation from neighboring pulses. Different pulse sequences are generally required for different magnetic-resonance measurement sequences.

Brief Summary Text (6):
A magnetic-resonance measurement sequence also typically involves digitizing at timed intervals the magnetic-resonance signals excited by the sequence of

radio-frequency pulses, accumulating digitized signals from a number of measurement runs for signal averaging, and digitally manipulating the accumulated digitized signals by Fourier transformation or other algorithm. For this reason, conventional pulse/Fourier-transform NMR spectrometers generally include a data processor which may be programmed to perform specified data-processing operations to analyze the magnetic-resonance signals excited by a particular pulse sequence.

Brief Summary Text (7):
Among the factors which can influence the selection of a particular pulse sequence and a particular set of data processing operations is the nature of the sample to be investigated. Thus, each time a new sample is introduced into the NMR spectrometer for analysis, it is ordinarily necessary for a user to enter instructions into the spectrometer specifying the measurement sequence to be used. NMR spectrometers configured for automatic operation may include an automatic sample changer for inserting a series of samples one-by-one into and withdrawing them from the spectrometer automatically. The user must ordinarily enter instructions into the spectrometer to program the operation of the automatic sample changer as well as to specify the measurement sequence to be used for each of the samples.

Brief Summary Text (8):
Modern pulse/Fourier-transform NMR spectrometers are capable of performing an almost bewildering variety and number of measurement sequences when account is taken of the many different NMR measurement experiments which can be performed and the many different nuclei and combinations of nuclei on which such experiments can be carried out. The measurement sequences to obtain the NMR spectra of different nuclei constitute different sequences since a user must specify the identity of the nucleus--or equivalently, its resonance frequency--to the spectrometer. Moreover, the number of such measurement sequences is increased inasmuch as the NMR spectra of the various nuclei can be obtained with or without the application of radio-frequency decoupling fields for effectively eliminating interactions with other types of nuclei in the sample. The number of measurement sequences for obtaining NMR spectra is further increased in that additional radio-frequency fields may be applied to suppress interfering resonance lines from solvents in which the sample is dissolved. Different measurement sequences are required to determine relaxation times of individual resonance lines using sequences of pairs of radio-frequency pulses of differing widths--for example, a 180.degree. pulse followed by a 90.degree. pulse--and incrementally varying the time interval between the pulses of the pair. In still other measurement sequences of which many modern pulse/Fourier spectrometers are capable, two-dimensional spectra may be obtained which reveal interactions between different nuclei in a sample. Polarization may be transferred from one group of nuclei to another by measurement sequences such as an experiment referred to as the distortionless enhancement by polarization-transfer experiment--also referred to as the "DEPT" experiment. In general, a user must specify which of these and many other measurement sequences the pulse/Fourier-transform spectrometer is to perform on a sample in a given experiment.

Brief Summary Text (9):
In addition, conventional pulse/Fourier-transform NMR spectrometers are capable of locking the magnetic field of the spectrometer to resonance signals of a variety of nuclei in a locking channel. Optimizing the locking typically involves adjusting parameters such as the power of a radio-frequency field in the locking channel of the spectrometer, the gain of a receiver in the locking channel and the phase of a magnetic-resonance signal used for locking. A user must ordinarily specify at least the nucleus and compound from which the locking signals are to be obtained, and, in many spectrometers, may specify the values of the locking-channel parameters as well.

Brief Summary Text (10):
To produce a highly homogeneous magnetic field typically required in magnetic resonance spectroscopy, currents through various magnetic-shim coils must be adjusted. Modern high-resolution magnetic-resonance spectrometers in general perform such field shimming adjustments automatically. However, different samples and different experimental procedures may require different strategies for optimizing the shimming. Consequently, the user may have to specify the shimming procedure to be used in a given experiment.

Brief Summary Text (11):
A user is faced with additional parameters to specify which relate to collecting

magnetic-resonance signal data in specifying a measurement sequence for a conventional pulse/Fourier-transform NMR spectrometer. For example, the phase, the gain, and the bandwidth of a receiver channel of the spectrometer must be specified for each measurement sequence. In addition, the interval between the times the signal is sampled must be specified.

Brief Summary Text (12):
The user of a pulse/Fourier-transform NMR spectrometer must provide further specifications in connection with processing the digitized magnetic-resonance signals for the display and analysis. For example, the user typically must specify selections for the measurement sequence in connection with correcting phase errors, compensating for base-line drift, and defining regions for integrating line intensities. In addition, the media on which the resulting spectra are to be displayed must be specified, along with scaling parameters and whether or not spectral lines will be identified digitally.

Brief Summary Text (13):
Largely as a result of the great number of different items which a user must specify in performing even routine magnetic-resonance measurements on a modern pulse/Fourier-transform NMR spectrometer, such spectrometers tend to be intimidating to users who may desire the results of magnetic-resonance measurements, but who are not experts in magnetic-resonance measurement technology.

Brief Summary Text (14):
Attempts have been made in the past to simplify the operation of NMR spectrometers so that magnetic- resonance measurements could be carried out by persons who are not expert in magnetic-resonance measurement technology. In certain cases such attempts have simplified spectrometer operations somewhat, but there remains room for improvement.

Brief Summary Text (15):
For example, a series of pulse/Fourier-transform NMR spectrometers commercially available from Bruker Instruments Inc. of Billerica, Massachusetts under the trade designation "AM"-series spectrometers has been capable of performing a variety of magnetic-resonance measurements on a number of different nuclei. Each "AM"-series spectrometer has included a computer for controlling the spectrometer as well as for storing and processing the signals obtained from the magnetic-resonance experiments. Software has been available for the computer which, on the one hand, has allowed a specialist in magnetic-resonance measurement technology to have access to the full range of the capabilities of the spectrometer, and which, on the other hand, has permitted less-experienced users to perform routine experiments without requiring them to specify the details of spectrometer operation. A menu of descriptive information has been provided which was invoked by typing a "HELP" command on the keyboard. A menu-driven procedure has been available for specifying experiments for obtaining routine NMR spectra--including certain two-dimensional spectra which directed the user to supply necessary spectrometer-control instructions through a dialogue procedure. The selected spectrometer-control instructions served to invoke control routines in the computer for controlling the operation of the spectrometer. Appropriate sets of parameters were retrieved from a magnetic disk for performing the specified experiment.

Brief Summary Text (16):
For entering spectrometer-control instructions from a user, the "AM"-series of NMR spectrometers have heretofore included a terminal in form of a console having a keyboard, a display and an interface/control system. The display of the terminal was capable of displaying the menu of instructions from which the user could select by typing on the keyboard and displaying the instructions so selected. However, the typing of a series of spectrometer-control instructions tended to be an exacting task which too often led to errors. Although certain typing errors could be detected and rejected by the terminal interface/control system when they were recognizable as syntax errors, correctly-typed, but inappropriate instructions could not in general be detected and tended to cause trouble since such instructions could launch the spectrometer on sequences of inappropriate operations.

Brief Summary Text (17):
A mouse for controlling the position of a cursor on the display has also been available for spectrometer-control instruction input in the "AM"-series of spectrometers. Another conventional pulse Fourier-transform spectrometer has employed a light pen and a CRT for entering spectrometer-control instructions. A

conventional magnetic-resonance tomographic imaging device heretofore available has used a touch-sensitive CRT for entering instructions for controlling the device.

Brief Summary Text (18):
The computer software for the "AM"-series of NMR spectrometers also includes a password system which is intended to prevent one user from accessing or destroying the files of another user. In addition, the software password system is programmed to prevent users other than a designated system manager from altering the system software and the basic interface between the software and the spectrometer. However, if an unauthorized person learns the password of the system manager, the person can be in a position to make changes to the fundamental system software and software/spectrometer interface without the system manager's knowledge. Moreover, even an inexperienced user using his or her own password is permitted to bypass the menu-driven procedure for routine experiments and directly alter spectrometer settings and experimental parameters. A subsequent user can experience error, confusion, and delay when a prior user changes spectrometer settings and experimental parameters to nonstandard values and does not return them to expected standard values prior to leaving the spectrometer for the subsequent user.

Brief Summary Text (19):
Among the features heretofore available on the Bruker "AM"-series NMR spectrometer was an automated sample changer. The sample changer had an array of sample holders for holding sample tubes containing samples to be analyzed. The sample tubes were labelled with barcoded labels. The sample changer included a barcode reader mounted on the changer which was capable of reading the labels of the sample tubes one at a time. The sample changer was adapted to transfer selectively a sample tube identified by a predetermined label to the magnet.

Brief Summary Text (20):
European published patent application No. 86302595.3, published Oct. 15, 1986 under publication No. 0197791, disclosed an automated apparatus for presenting samples to an NMR spectrometer. The apparatus employed a reflective coding label affixed to a sample carrier for identifying the sample and prescribing the operating parameters of the spectrometer. An LED light source and a photodiode optical detector were mounted in the probe of the spectrometer adjacent to a sample-carrier-receptacle cavity for reading the reflective coding labels of sample carriers inserted in the cavity. Evidently, to make any change in the operating parameters prescribed by a reflective coding label for a sample required the preparation of a new reflective coding label, removing the label previously affixed to the sample carrier, and affixing the new label in place of the previous label, a major inconvenience.

Brief Summary Text (22):
We have invented a magnetic-resonance instrument which provides for convenient input of measurement-sequence specification information in which the danger of input errors is substantially reduced and which avoids problems of the prior art noted above.

Brief Summary Text (23):
Broadly, the magnetic-resonance instrument of the invention comprises a magnet for generating a magnetic field and a probe positionable in the magnet for positioning test matter to be analyzed in the magnetic field. Such test matter could include, for example, a sample of a chemical compound whose NMR spectrum is desired or a body to be imaged tomographically. The probe includes radio-frequency coupling circuitry for coupling radio-frequency signals between the test matter and the coupling circuitry. In the case of an NMR spectrometer, the coupling circuitry may comprise, for example, a solenoidal sample coil. In the case of a magnetic-resonance tomographic imaging device, the coupling circuitry may comprise, for example, a probe-head resonator circuit.

Brief Summary Text (24):
The magnetic-resonance instrument of the invention further comprises a radio-frequency generator/transmitter connected to the coupling circuitry of the probe. The generator/transmitter is capable of generating and amplifying radio-frequency excitation signals for exciting magnetic-resonance signals from the test matter in the probe in accordance with a magnetic-resonance measurement sequence. The timing of the excitation signals is specified by control signals applied to the generator/transmitter.

Brief Summary Text (25):

The magnetic-resonance instrument of the invention further comprises a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe for amplifying and detecting magnetic-resonance signals from the test matter and for digitizing the signals to form digitized magnetic-resonance signals.

Brief Summary Text (26):
The magnetic-resonance instrument of the invention further includes a digitized-signal averager/processor which is connected to the receiver/digitizer. The averager/processor is capable of accumulating and storing digitized magnetic-resonance signals from the receiver/digitizer and digitally processing the stored signals for interpretation and display. Processing operations carried out by the averager/processor are specified by control signals applied to the averager/processor.

Brief Summary Text (27):
The magnetic-resonance instrument of the invention further comprises a programmable instrument controller having measurement-sequence control-program storage for storing a plurality of measurement-sequence control programs. Each measurement-sequence control program specifies one of a plurality magnetic-resonance measurement sequences which the magnetic-resonance instrument is capable of carrying out. As used herein, the term "measurement-sequence control program" can refer to any program, routine, subprogram or subroutine, or to any collection of programs, routines, subprograms, or subroutines--and to any associated data--which performs an instrument control function for a magnetic-resonance measurement sequence. Associated with each measurement-sequence control program is a digital control-program identifier for identifying the control program. The instrument controller is adapted to recall and execute selectively a measurement-sequence control program identified by a specified control-program identifier to generate control signals for the magnetic-resonance measurement sequence specified by the control program. The instrument controller is connected to the radio-frequency generator/transmitter for applying control signals to the generator/transmitter to specify the timing of the radio-frequency excitation signals generated by the generator/transmitter. The instrument controller is also connected to the digitized-signal averager/processor for applying control signals to the averager/processor to specify processing operations carried out by the averager/processor.

Brief Summary Text (28):
The magnetic-resonance instrument of the invention also includes a barcode reader which is connected to the instrument controller for reading barcode-encoded data words and transmitting signals representative of such data words to the instrument controller. A plurality of barcode-encoded data words define measurement-sequence data words. For each of a plurality of magnetic-resonance measurement sequences which the magnetic-resonance instrument is capable of carrying out, one or more barcode-encoded measurement-sequence data words constitute measurement-sequence specification information sufficient to specify the measurement sequence at least to an extent of permitting the control-program identifier associated with a measurement-sequence control program which specifies the measurement sequence to be identified. The instrument controller is adapted to receive signals from the barcode reader representative of the one or more barcode-encoded measurement data words which constitute measurement-sequence specification information specifying a measurement sequence and to recall and execute the measurement-sequence control program identified by the control-program identifier identified in the measurement-sequence specification information.

Brief Summary Text (29):
Finally, the magnetic-resonance instrument of the invention includes one or more measurement-sequence-selection barcode tables. Each measurement-sequence-selection barcode table has a plurality of barcode-encoded measurement-sequence data words arranged on it. Each barcode-encoded measurement-sequence data word on the barcode table is selectively readable by a user with the barcode reader to transmit signals to the instrument controller representative of the measurement-sequence data word. The measurement-sequence-selection barcode table has a plurality of measurement sequences associated with it which the magnetic-resonance instrument is capable of carrying out. Each of the measurement sequences associated with the barcode table can be specified by magnetic-sequence specification information constituted by one or more of the barcode-encoded measurement-sequence data words included on the barcode table. A user can thus cause the magnetic-resonance instrument to selectively perform a magnetic-resonance measurement sequence specified by one of

the measurement-sequence control programs associated with a measurement-sequence-selection barcode table by reading a corresponding one or more of the barcode-encoded measurement-sequence data words on the measurement-sequence-selection barcode table with the barcode reader.

Brief Summary Text (30):
Preferably, the barcode reader of the magnetic resonance instrument of the invention is a hand-holdable wand. The barcode-reader wand is preferably connected to the instrument controller of the magnetic-resonance instrument by means of a flexible signal-transmission cable for transmitting signals encoding data representative of barcode-encoded data words read with the wand to the instrument controller. A suitable hand-holdable barcode-reader wand is commercially available under the trade designation "HBCS-2300" from the Hewlett-Packard Company of Palo Alto, Calif. In a preferred embodiment, the magnetic-resonance instrument of the invention includes a console having a control panel and the measurement-sequence-selection barcode table is removably attachable to the control panel. The preferred hand-holdable barcode-reader wand is attached to the console by the signal-transmission cable. Alternatively, a fixed-position barcode reader may be installed in a console of a magnetic-resonance instrument of the invention and a barcode table may be read by positioning the table over the reader.

Brief Summary Text (31):
The barcode reader of the magnetic-resonance instrument of the invention permits the task of entering measurement-sequence specification information into the instrument to be carried out simply, since the task involves only the reading of barcode-encoded data words constituting the specification information by means of the barcode reader. Because of the simplicity by which the measurement-sequence specification information may be entered, the input of the information tends to be free of errors.

Brief Summary Text (32):
The barcode-encoded data words on the measurement-sequence-selection barcode table are preferably labelled to indicate the instructions or data to which the data words correspond. In preferred embodiments of the invention, barcode-encoded data words appropriate to a single type of measurement sequence are grouped together on a single measurement-sequence-selection barcode table. In this way, any danger of a user's intermixing instructions or data appropriate to different types of measurement sequences is reduced. Moreover, the measurement-sequence-selection barcode table preferably includes arrows or other notations indicating the sequence in which the measurement-sequence data words on the barcode table are to be entered.

Brief Summary Text (33):
The measurement-sequence-selection barcode table of the invention is preferably in the form of a paper, cardboard or plastic sheet on which the barcode-encoded data words and associated labels are printed. Preferably, the magnetic-resonance instrument of the invention includes a plotter or other hard-copy display-output device for producing plots or other hard-copy display images of magnetic-resonance data. The instrument controller of the magnetic-resonance instrument is preferably programmed to produce measurement-sequence-selection barcode tables on the plotter or other hard-copy display output device of the instrument.
Measurement-sequence-selection barcode tables can be readily reproduced on a photocopy machine.

Brief Summary Text (34):
If desired, several measurement-sequence-selection barcode tables can be bound together to form a booklet. It can be advantageous at certain magnetic-resonance instrument installations to prepare a booklet of measurement-sequence-selection barcode tables tailored for each user of the instrument. The booklet for a particular user would include barcode tables for those magnetic-resonance measurement sequences which the user was qualified or authorized to carry out. For example, a beginning user might not be authorized to perform certain measurement sequences to generate two-dimensional NMR spectra which might require hours of instrument time to complete. In addition, the measurement-sequence control programs specified in the measurement-sequence-selection barcode tables for less experienced users can employ standard values automatically for more of the required parameters, whereas corresponding measurement-sequence control programs specified in the barcode tables for more experienced users can leave it to each user to specify the values for the parameters which he or she deems best for the particular circumstances.

Brief Summary Text (35):
Preferred magnetic-resonance instruments of the invention include a display such as a CRT monitor connected to the instrument controller for displaying messages to the user. Preferably, the instrument controller is programmed to display a message confirming the measurement-sequence data word previously entered from the measurement-sequence-selection barcode table and indicating from which group on the barcode table the next data word is to be read.

Brief Summary Text (36):
In a preferred magnetic-resonance instrument of the invention in the form of a pulse/Fourier-transform spectrometer, an instrument controller embodied as a spectrometer controller includes a computer for exercising control of the functions of the spectrometer by executing spectrometer control programs, including measurement-sequence control programs. Each measurement-sequence control program when it is run specifies a particular NMR measurement sequence, including the sequence of steps to be carried out to excite the NMR signals; to detect, digitize and store the resulting signals; and to process and display the stored data. Measurement-sequence control programs and other spectrometer-control programs can be entered into the computer of the spectrometer controller from a keyboard of a terminal of the spectrometer.

Brief Summary Text (37):
The entry of spectrometer-control programs into the computer of a spectrometer controller of an NMR spectrometer of the invention is preferably restricted to a limited number of persons designated spectrometer managers who are accorded a privileged level of access to the software of the spectrometer controller. The spectrometer managers are identified by a confidential identification code which is encoded in barcode and printed on a card--preferably of pocket size--issued to each spectrometer manager. The barcode-encoded identification code on the card must be read by the barcode reader of the spectrometer and verified by the computer of the spectrometer controller before entry or fundamental alteration of a spectrometer-control program is permitted by the controller. Even after the spectrometer manager has been identified by the barcode-encoded identification code, additional passwords are preferably required to be entered by the manager before a spectrometer control program may be entered or fundamentally altered.

Brief Summary Text (38):
If a card bearing the barcode-encoded identification code of a spectrometer manager were lost or stolen, the spectrometer manager would learn that the card was missing at least by the time he or she attempted to use the spectrometer. In that event the spectrometer manager could initiate cancellation of the identification code printed on the missing card, thereby denying a holder of the lost or stolen card the privileged level of access to the software of the spectrometer controller to which the spectrometer manager was entitled.

Brief Summary Text (39):
In addition, the spectrometer of the invention preferably includes an entry-mode switch at a restricted location within the cabinet of the spectrometer to enable the spectrometer to be set in a spectrometer-control-program entry mode by a service technician or the like who has access to the interior of the cabinet.

Brief Summary Text (40):
For a preferred high-resolution pulse/Fourier-transform NMR spectrometer of the invention, two classes of measurement-sequence specification information are provided by each measurement-sequence control program as the program is run: (I) magnetic-resonance signal excitation and acquisition information, and (II) acquired magnetic-resonance-data processing and output information.

Brief Summary Text (41):
Among the items of magnetic-resonance signal excitation and acquisition information provided for such a spectrometer by preferred measurement-sequence control programs as the programs are run are: (1) the center frequency of a measurement channel, e.g. the approximate magnetic-resonance frequency of protons, carbon-13, or other types of nuclei in the magnetic field of the magnet of the spectrometer, (2) the frequency of the locking channel, e.g. the particular frequency of the proton, deuterium or other nuclear magnetic resonance line from the particular chemical compound used for locking the magnetic field, (3) the width, the intensity, the phase, and the spacing of the radio-frequency pulses applied to the sample from the measurement channel in

each measurement run, e.g. the pulse sequence of the experiment, (4) a flag specifying whether or not a radio-frequency decoupling signal is to the applied to the sample from a decoupling channel, and, if so, the frequency, the power level, and the timing of the decoupling signal, (5) the number of digitized data points to be collected in each measurement run, (6) the time interval between data points, (7) a delay interval between measurement runs, and (8) a flag specifying a termination criterion for the number of measurement runs, e.g. a minimum-signal-to-noise criterion or a fixed-number-of-runs criterion, for which latter criterion the number of runs is also specified. Of the items of excitation and acquisition information listed, the spectrometer of the invention preferably permits the following to be selected by a user reading appropriate barcode-encoded data words from a measurement-sequence-selection barcode table using the barcode reader of the spectrometer: (1) the nucleus to be examined, which determines a center frequency for the measurement channel; (2) the chemical compound used for locking, which determines the frequency of the locking channel; (3) the pulse sequence of the experiment, which identifies the measurement-sequence control program to be executed, which program in turn taking into account the nucleus selected by the user specifies appropriate standard widths, phases, intensities, and spacings for the radio-frequency pulses in the measurement channel, appropriate standard timing for the decoupling signal (if any), an appropriate number of data points, an appropriate spacing between data points, an appropriate delay interval between measurement runs, and a suitable termination criterion for the number of measurement runs; and (4) whether or not a second nucleus is to be decoupled, and, if so, the identity of the second nucleus, which determines whether or not a decoupling signal will be applied, its frequency and an appropriate power level.

Brief Summary Text (42):
Among the items of acquired magnetic-resonance-data processing and output information provided for such a spectrometer by preferred measurement-sequence control programs as the programs are run are: (1) specification of window-function parameters for digital filtering, (2) a flag specifying whether or not resonance peaks are to be integrated, and, if so, specification of the spectral range over which the integration is to be carried out, (3) a flag specifying whether or not to carry out automatic base-line correction, (4) a pointer specifying the media for display or storage of spectral data, and, as appropriate, specification of display parameters, e.g. the pointer may specify that an NMR spectrum be displayed on the CRT monitor of the spectrometer or plotted on the spectrometer plotter with specified scaling, and (5) a flag specifying whether or not spectral peak positions and intensities are to be printed, and, if so, specification of a cut-off intensity value for peak identification. Of the items of acquired data processing and output information listed, the spectrometer of the invention preferably permits the following to be selected by a user reading appropriate barcode-encoded data words from a measurement-sequence-selection barcode table using the barcode reader of the spectrometer: (2) whether or not to integrate resonance peaks, (3) whether or not to carry out automatic base-line correction, (4) selection of display or storage media, and (5) whether or not to print spectral peak positions and intensities. For routine measurement sequences, standard numerical values appropriate for the choices specified by the user are preferably provided automatically by the measurement-sequence control program. Alternatively, the spectrometer-control program can unlock the keyboard of the spectrometer to enable numerical values to be entered by the user.

Brief Summary Text (43):
Another item of measurement-sequence-specification information which can be provided for a pulse/Fourier-transform NMR spectrometer of the invention by a preferred measurement-sequence control program is specification of whether or not the temperature in the probe is to be controlled, and, if so, a desired temperature value. A user may specify that the temperature in the probe is to be controlled by reading a barcode-encoded data word from a measurement-sequence-selection barcode table of the invention. The desired temperature could be entered by way of the keyboard of the spectrometer in the case the spectrometer had a temperature controller, for the probe which was computer controlled, or by way of controls on the temperature controller in the case the spectrometer had a manually-settable temperature controller.

Brief Summary Text (44):
Further items of measurement-sequence specification information which can be provided for a pulse/Fourier-transform NMR spectrometer of the invention by a preferred measurement-sequence control program include identification of replaceable

parts used in the spectrometer, e.g. probes of various frequencies and bore sizes. Preferably, such replaceable parts are labelled with a label bearing a barcode-encoded part-identification code which may be read by the barcode reader of the spectrometer to identify the part.

Brief Summary Text (45):
Preferably, the measurement-selection barcode tables of the invention include barcode-encoded data words which control the progress of the measurement sequences carried out on the magnetic-resonance instrument. For example, barcode-encoded data words are preferably included on the barcode table initiating entry of the measurement-sequence-specification information, instructing the spectrometer to eject any previous sample in the probe, instructing the spectrometer to insert a new sample into the probe, and initiating the measurement sequence itself. The measurement-sequence-selection barcode table preferably includes additional data words to provide for affirmative and negative replies to questions presented on the CRT monitor of the spectrometer. Such questions may inquire as to whether or not a new measurement sequence is to be carried out on the sample presently in the spectrometer, or whether or not a new sample is to be inserted in place of the present sample.

Brief Summary Text (46):
Each measurement-sequence control program is preferably identified by a unique program identifier assigned by the spectrometer manager or other programmer who created the program. Reading one or more barcode-encoded data words from a measurement-sequence-selection barcode table to enter user-specified measurement-sequence specification information preferably causes a master control program running in the spectrometer controller to identify a measurement-sequence control program for the specified measurement sequence, to incorporate in the program a set of excitation and acquisition parameters and acquired-data processing and output parameters either directly specified by the barcode-encoded data words entered by the user or automatically selected taking into account the data words entered by the user, and to execute the program.

Brief Summary Text (47):
A magnetic-resonance instrument of the invention in the form of a magnetic-resonance tomographic imaging device preferably has an instrument controller which is programmed to permit only persons who enter a valid barcode-encoded identification code via the barcode reader of the device to operate the device. Each qualified operator of the tomographic imaging device is preferably issued a card--preferably of pocket size--bearing such a barcode-encoded identification code which identifies the operator. Access to a magnet room in which the magnet of the tomographic imaging device is located is preferably controlled by the instrument controller of the device by means of a remote-controlled lock on each door to the magnet room. In this way access to the magnet room can be limited to persons who enter a valid barcode-encoded identification code into the instrument-controller of the magnetic-resonance tomographic imaging device. A magnet-room-access auxiliary barcode reader located close to a door to the magnet room and connected to the instrument controller may facilitate the reading of the identification codes of persons who wish to enter the magnet room.

Brief Summary Text (48):
Preferably, each patient examined by the magnetic-resonance tomographic imaging device of the invention is assigned a unique barcode-encoded patient-identification code. The doctor in charge of the tomographic-imaging examination is also preferably assigned a unique barcode-encoded doctor-identification code. Both the patient identification code and the doctor-identification code in barcoded form are preferably taken with the patient to the magnet room and read immediately prior to the examination to confirm the identity of the patient. For this purpose, the barcode-encoded patient identification code of the patient and the doctor-identification code of his or her doctor is preferably printed on a nonmagnetic wristband worn by the patient during the examination. The instrument controller for the magnetic-resonance imaging device is preferably programmed not to allow the examination to proceed until the identity of the patient is established by reading of the barcode-encoded patient and doctor-identification codes. Preferably, a magnet-room auxiliary barcode reader connected to the instrument controller is located in the magnet room and may be used to read the barcode-encoded patient and doctor identification codes of the patient. The patient and doctor identification codes are preferably printed on each tomographic image taken of the patient for purposes of identification, as well as on any printout of data pertaining to the

examination produced by the tomographic imaging device.

Brief Summary Text (49):
Preferably, the magnetic-resonance tomographic imaging device of the invention permits an operator to specify the following items of measurement-sequence specification information by reading selected barcode-encoded measurement-sequence data words from one or more measurement-sequence-selection barcode tables using the barcode reader of the device: (1) the body part to be imaged, e.g. head, torso, leg; (2) the type of image, which determines the tomographic-imaging pulse and magnetic-gradient sequence to be applied; (3) the number and spacing of the slices to be imaged; (4) a flag specifying whether or not to activate automatic radio-frequency tuning; (5) a flag specifying whether or not to activate automatic magnetic-field shimming; and (6) identification of replaceable parts employed in the tomographic imaging device, e.g. replaceable probe coupling circuits such as surface coils of various conformations and bird-cage resonators of various forms and capacities. In connection with the identification of replaceable parts employed in the device, it is preferred that each such replaceable part be labelled with a barcode-encoded part-identification code. The presence of the part in the tomographic imaging device could then be verified by reading the part-identification code of the part in the device with the magnet-room auxiliary barcode reader. The instrument controller of the device is preferably programmed not to permit the examination to proceed until the identity of the replaceable parts is confirmed by reading the part-identification codes labelling such parts in the device. The instrument controller can verify that each of the replaceable parts present in the device has an adequate power rating and is otherwise suitable for the tomographic imaging measurement sequence specified.

Brief Summary Text (50):
In addition, the progress of a tomographic examination is preferably controlled in a magnetic-resonance tomographic imaging device of the invention by reading of barcode-encoded data words from a measurement-sequence-selection barcode table. Barcode-encoded data words selected by an operator could cause the device to advance to the next step of the measurement sequence, hold the present state of the device to the extent that it is safe to do so, escape from barcode control, and abort the imaging process.

Brief Summary Text (51):
Preferred magnetic-resonance instruments of the invention are flexible in that new measurement-sequence control programs may be written to specify new magnetic-resonance measurement sequences which users desire to run on the instrument. Each such new measurement-sequence control program can be assigned a control-program identifier which is identified by measurement-sequence specification information from one or more barcode-encoded measurement-sequence data words. Thereafter, users can carry out the new measurement sequence by entering the appropriate barcode-encoded measurement-sequence data word or words by way of the barcode reader of the instrument.

Brief Summary Text (52):
Advantageously, preferred magnetic-resonance instruments of the invention may be operated by persons who have no knowledge of the software needed to control the instrument. The specification of measurement sequences can proceed quickly. For example, only four barcode-encoded data words need to be entered to select and begin a routine NMR measurement sequence in one preferred pulse/Fourier-transform spectrometer of the invention.

Drawing Description Text (3):
FIG. 1 shows a schematic block-diagram of a preferred NMR spectrometer of the invention.

Detailed Description Text (2):
Turning now to FIG. 1, an NMR spectrometer 1 comprises a magnet system providing an essentially homogeneous magnetic field in which a probe head is positioned. The magnetic system and the probe head are identified collectively in FIG. 1 as magnet and probe head unit 11. A radio-frequency transmitter 13 and a receiver 15 are connected to the probe head of unit 11.

Detailed Description Text (3):
A pulse programmer 17 is connected to the radio-frequency transmitter 13 in order to control the sequences of radio-frequency pulses produced by the transmitter 13 and

applied to the probe head. A data processor 19 is connected to an output of the receiver 15. The data processor 19 is capable of accumulating and storing magnetic-resonance signals detected and digitized by the receiver 15 and digitally processing the stored digitized signals for analysis and display.

Detailed Description Text (4):
An automatic sample changer 21 is connected to the probe head in the magnet and probe head unit 11. The automatic sample changer 21 is adapted to store up to about 120 NMR sample tubes in a generally circular sample-holder carousel and to rotate the carousel stepwise to position a selected sample tube in the carousel at a sample-tube take-off/return position. The automatic sample changer is further adapted to withdraw a sample tube located at the take-off/return position, then to insert the sample tube into the probe head for measurement, and, after the measurement is completed, to remove the sample tube from the probe head and replace it in the sample-holder carousel of the sample changer at the take-off/return position. Each sample tube can have a generally-cylindrical label collar mounted axially on it to which an adhesive label may be affixed. A barcode-encoded sample-identification code can be printed on the label to identify the sample. The automatic sample changer 21 includes a sample-tube-label barcode reader mounted in a position to read barcode-encoded sample-identification codes on the sample tubes having collars with labels bearing such codes.

Detailed Description Text (5):
The pulse programmer 17, the data processor 19, the automatic sample changer 21, and the sample-tube-label barcode reader are connected to a spectrometer controller housed in a terminal 23. The spectrometer controller includes a digital computer having read/write storage and a magnetic-disk storage unit for storing spectrometer control programs for controlling the pulse programmer 17, the data processor 19 and the automatic sample changer 21. The terminal 23 comprises a keyboard 27 and a CRT monitor 29 for data display. A hand-holdable barcode-reader wand 31 is connected to the terminal 23 by a flexible signal-transmission cable 33. Positioned adjacent to the keyboard 27 is a control panel 25 on which a measurement-sequence-selection barcode table 35 is removably mounted. FIG. 2 illustrates in greater detail a preferred measurement-sequence-selection barcode table 135 for a manual operating mode of the spectrometer.

Detailed Description Text (6):
Turning now to FIG. 2, the measurement-sequence-selection barcode table 135 is a cardboard sheet having a corner cutout 137 and a keyrow cutout 139. The keyrow cutout 139 is dimensioned so that a top row of keys of the keyboard 27 fits through the cutout to hold the barcode table in place. The corner cutout 137 provides clearance for certain indicator lights (not shown) mounted in the control panel 25 of the terminal 23 to be seen with the barcode table 135 in place.

Detailed Description Text (7):
The measurement-sequence-selection barcode table 135 has 38 barcode-encoded data Words printed on an upper surface of the table. The 38 barcode-encoded data words are arranged in five groups. An experiment-initiation group 150 includes a first data word 152 labelled "Start Experiment" and a second data word 154 labelled "Insert Sample." A user-identification group 156 includes eight barcode-encoded data words labelled "User 1" through "User 8," respectively. Positioned below the user-identification group 156 of data words is an experiment/solvent group 160 of 25 barcode-encoded data words arranged in a five-by-five array. The five rows of the array are labelled with the following five solvents which are commonly used to dissolve samples in high-resolution NMR experiments and which have resonance lines suitable for locking the magnetic field: acetone, benzene, CDCl.sub.3, D.sub.2 O and DMSO. The five columns of the experiment/solvent group 160 are labelled with the following five labels: ".sup.1 H," ".sup.1 H S/N ABORT," ".sup.13 C," "13C S/N ABORT," and ".sup.13 C Multiplicity Analysis." To the right of the experiment/solvent 160 of data words is a Yes/No group 172 of data words, consisting of a data word 174 labelled "Yes" and a data word 176 labelled "No." Finally, an inject group containing a single barcode-encoded data word 178 labelled "Inject" is located below the Yes/No group 172 of data words. As may be seen in FIG. 2, arrows are drawn on the barcode table 135 from the experiment-initiation group 150 to the user-identification group 156, from the user-identification group 156 to the experiment/solvent group 160, from the experiment/solvent group 160 to the Yes/No group 162, and from the Yes/No group 172 to the inject group 178.

Detailed Description Text (8):

In operation, a master control program executed by the computer of the spectrometer controller provides supervisory control of the operation of the spectrometer. The master control program controls the input of spectrometer control information into the spectrometer controller from both the keyboard 27 and the barcode reader 31. The master control program distinguishes between ordinary users and spectrometer managers. A spectrometer manager is recognized by the spectrometer controller running the master control program by an identification code unique to the manager entered by way of the barcode reader.

Detailed Description Text (9):
A spectrometer manager, once so identified, can instruct the master control program to place the spectrometer in a number of operating modes. A master-control-instruction barcode table has barcode-encoded data words printed on it which can be entered into the spectrometer controller by a spectrometer manager using the barcode-reader wand 31 to specify the various operating modes. One such operating mode is a restricted barcode-encoded information entry mode. With the spectrometer in the restricted barcode-encoded information entry mode, the keyboard 27 of the spectrometer is effectively locked and users can enter spectrometer-control information into the spectrometer controller--with limited exceptions--only by way of the barcode reader 31. Another operating mode which can be specified by a spectrometer manager is a manual-sample-insertion operating mode or an automatic-sample-changer operating mode.

Detailed Description Text (10):
In operation, with the spectrometer in the manual-sample-insertion operating mode and in the restricted barcode-encoded information entry mode, a user enters barcode-encoded data words into the spectrometer controller by gently moving the barcode-reader wand 31 over a selected data word on the measurement-sequence-selection barcode table 135. Entry of the "Start Experiment" data word 152 from the experiment-initiation group 150 on the barcode table 135 initiates the sequence of an experiment by turning on the sample-lift air jet of the probe. A message is then displayed on the CRT monitor 29 to exchange or insert a sample tube. The user inserts a sample tube in a sample-insertion port and then enters the "Insert-Sample" data word 154 of the experiment-initiation group 150 by using the barcode-reader wand 31. Entry of the "Insert-Sample" data word 154 causes the sample-lift air jet to terminate and the sample tube to settle into the probe in the magnet. A message is then displayed on the monitor 29 instructing the user to enter a user code. The user then enters one of the eight user-identification data words in the user identification group 156. The user-identification code thus selected is employed to identify all data collected in the measurement sequence.

Detailed Description Text (11):
After the user-identification code is entered, a message is displayed on the monitor instructing the user to enter an experiment/solvent combination. The user selects a desired experiment corresponding to one of five columns of the experiment/solvent group 160 on the measurement-sequence-selection barcode table 135. In addition, the user identifies which of the five solvents associated with the rows of the experiment/solvent group 160 was used as a solvent for the sample in the sample tube. If the desired experiment and solvent combination is not found on the measurement-sequence-selection barcode table 135, the user must choose another barcode table which includes the desired combination. Reading the barcode-encoded data word corresponding to the column of the desired experiment and the row of the solvent with the barcode-reader wand enters an experiment/solvent combination into the spectrometer controller. A message is then displayed on the CRT monitor 29 requesting an optional plot title. The keyboard is unlocked to permit the user to input a title if desired. The spectrometer controller then recalls and executes an appropriate measurement-sequence control program to carry out the desired measurement. All parameters required for the measurement sequence are automatically set to standard values, and data acquisition and processing is started. In particular, the measurement-sequence-control program automatically takes care of shimming the magnet, rotating the sample tube, locking the magnetic field to the specified solvent line, adjusting the receiver gain, selecting an appropriate criterion for determining the number of measurement runs, accumulating and Fourier-transforming or otherwise processing the data optimizing the spectral width in the case of two-dimensional experiments, carrying out carbon multiplicity analysis automatically should that experiment have been selected, plotting spectra with integrals and automatic expansion, and optimizing the plots of two-dimensional spectra.

Detailed Description Text (12):
When the measurement sequence is finished, the CRT monitor 29 displays a message asking whether another experiment with the same sample is desired. The user answers the question by reading with the barcode-reader wand 31 either the Yes data word 174 or the No data word 176 in the Yes/No group of data words 172. If the Yes data word 174 is selected, a message to enter a desired experiment/solvent combination is displayed on the monitor 29 and the procedure continues as explained above.

Detailed Description Text (13):
If the No data word 176 is read with the barcode reader wand 31, the monitor displays a message asking if the user wishes to perform an experiment on a different sample. The user must again respond to the question by selecting one of the Yes and No data words in the Yes/No group 172.

Detailed Description Text (14):
If the user responds by selecting the Yes barcode-encoded data word 174, the sample-lift air jet is actuated and the previous sample tube in the probe is raised to the sample-insertion port. A message is then displayed requesting that the samples be exchanged. After the user exchanges the samples by removing the previous sample tube from the sample-insertion port and replacing it with a new sample tube, the injection data word 178 is read, which causes the sample-lift air jet to be turned off and the new sample tube to settle into the probe. The CRT monitor 29 then displays a message requesting selection of an experiment/solvent combination and the procedure continues as explained above.

Detailed Description Text (15):
If the user responds by selecting the NO barcode-encoded data word 176, the sample tube in the probe is raised to the sample-insertion port with the sample-lift air jet. A message on the CRT monitor asks the user remove the sample from the sample-insertion port and to turn off the sample-lift air jet by entering the injection data word 178. The spectrometer is then free for use by others.

Detailed Description Text (16):
When the spectrometer is in the restricted barcode-encoded information entry mode and the automatic-sample-changer operating mode, a measurement-sequence-specification barcode table is used which is generally similar to the barcode table 135 illustrated in FIG. 2, but in which certain of the barcode-encoded data words and their associated labels on the table are different. When the spectrometer is placed in the automatic-sample-changer operating mode, the monitor 29 initially displays the message "User Identification." The spectrometer is free for use by ordinary users as well as spectrometer managers. A user enters one of eight barcode-encoded data words from a user-identification group of data words on the barcode table using the barcode-reader wand 31.

Detailed Description Text (17):
After entry of the user-identification code, the monitor 29 displays the message "Free for Input, Sample Identification." As noted above, the automatic sample changer 21 includes a sample-tube-label barcode reader positioned to read labels affixed to label collars mounted on sample tubes, which labels bear barcode-encoded sample-identification codes. The user enters a sample identification code by reading the barcode on the label of the sample tube using the hand-holdable barcode-reader wand 31.

Detailed Description Text (18):
After the sample identification code is read, the monitor displays the message "Experiment/Solvent." The measurement-sequence-selection barcode table for the automatic-sample-changer operating mode includes an experiment/solvent group of twenty-five barcode-encoded data words arranged in a 5.times.5 array generally similar to the experiment/solvent group 160 of the barcode table 135 of FIG. 2. By reading one of the barcode-encoded data words in the 5.times.5 array, the user specifies one of five experiments to be run on the sample and one of five solvents in which the sample is dissolved and which can provide a resonance signal for the locking channel.

Detailed Description Text (19):
After the experiment/solvent combination is selected, the RT monitor 29 of the spectrometer displays the message "Put Sample in Sample Holder, Verify by Entering Sample in Holder, Barcode." At this point, the user inserts the sample tube in the sample-holder carousel of the automatic sample changer and then reads a

barcode-encoded data word on the measurement-sequence-selection barcode table which is labeled "Sample in Holder" to verify that the sample tube has been placed in the sample-holder carousel.

Detailed Description Text (20):
The spectrometer then begins automatic background measurement operation; specifically, the spectrometer begins the measurement sequence for any samples to be measured in the automatic sample changer as a background measurement operation, while essentially simultaneously permitting users to enter measurement-sequence-specification information data for additional samples as a foreground data-entry operation. The master control program of the spectrometer controller begins the automatic background measurement operation by turning on the sample-lift air jet to eject any sample tube presently located in the probe and to transfer the sample tube to the sample-holder carousel of the automatic sample changer. The sample changer then advances the sample-holder carousel one position and the barcode-encoded sample-identification code on the sample-tube label of the next sample tube in the carousel, if any, is read. If the sample-tube-label identifies the sample as one which is to be measured, the spectrometer controller causes the automatic sample changer to transfer the sample tube to the sample-insertion port and to lower the sample tube into the probe. If the sample is not one which has been previously specified to be measured, or if there is no sample in that location in the sample-holder carousel, or if the sample is one which has already been measured, the spectrometer controller causes the automatic sample changer to advance the sample-holder carousel an additional position. The barcode-encoded sample-identification code on the sample-tube label of the sample in the next position, if any, is then read and the cycle repeats.

Detailed Description Text (21):
Once a sample tube has been loaded into the probe, the spectrometer-control program specified by the experiment/solvent combination entered for the sample is carried out. The data obtained from the measurement is stored under the user identification code of the user who entered the measurement-sequence-specification information for that sample. When the measurement is completed, the sample-lift air jet is turned on, the sample ejected and the process repeated for the next sample in the sample changer.

Detailed Description Text (22):
During the automatic background measurement operation, users may identify additional new samples in the foreground by first entering a barcode-encoded user-identification code, then reading the barcode-encoded sample-identification code on the sample-tube-label of each additional sample and finally reading a barcode-encoded data word specifying an experiment/solvent combination for the sample so identified. The sample tubes containing the additional samples may be placed at random positions in the sample-holder carousel. The automatic sample changer advances the carousel stepwise and all identified samples which have not previously been measured are measured as they reach the measurement position. Samples which have previously been measured or which have not been identified to the spectrometer controller by reading of their barcode-encoded sample-identification labels and entering an associated experiment/solvent combination are ignored.

Detailed Description Text (23):
The presence of a label collar and sample-tube-label on a sample tube can occasionally introduce a slight imbalance which causes the tube to wobble slightly as it spins in the probe. In certain circumstances such wobbling can introduce small spinning sidebands which usually are no greater than background noise and can be ignored, but which occasionally represent a problem in certain NMR experiments requiring extremely high resolution. In the present preferred spectrometer of the invention, such spinning sidebands can be avoided even with the spectrometer in the automatic-sample-changer operating mode. Specifically, a user can cause the automatic sample changer to hold a sample tube which does not carry a label collar in the sample-holder carousel at the take-off/return position. The user can bypass the barcode reader of the automatic sample changer and read a barcode-encoded sample-identification code for the sample with the hand-holdable barcode reader wand of the spectrometer. The spectrometer and automatic sample changer then process the sample tube without the label collar just as if the sample-identification code had been read from a label collar with the barcode reader of the automated sample changer.

Detailed Description Text (24):

A listing of a barcode-reader interface subroutine for a master control program for a preferred pulse/Fourier-transform NMR spectrometer of the invention written in the Pascal programming language for an "Aspect 3000" digital computer is attached hereto as Appendix A and made a part of this specification.

Detailed Description Text (25):
It is not intended to limit the present invention to the specific embodiments described above. It is recognized that changes may be made in the magnetic-resonance instrument described herein without departing from the scope and teaching of the instant invention and it is intended to encompass all embodiments, alterations and modifications consistent with the invention. ##SPC1##

Other Reference Publication (1):
K. Roth, NMR-Tomographie und-Spektroskopie in der Medizin, Eine Einfuhrung, Springer-Verlag, 1984.

CLAIMS:

1. A magnetic-resonance instrument programmable to perform a plurality of magnetic-resonance measurement sequences, comprising:

(a) a magnet for generating a magnetic field;

(b) a probe having radio-frequency coupling circuitry positionable in the magnet for coupling radio-frequency signals between the coupling circuitry and test matter to be analyzed in the magnetic field;

(c) a radio-frequency generator/transmitter connected to the coupling circuitry of the probe for generating and amplifying radio-frequency excitation signals in accordance with a magnetic-resonance measurement sequence for exciting magnetic-resonance signals from the test matter in the probe, the timing of the excitation signals being specified by control signals applied to the generator/transmitter;

(d) a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe for amplifying and detecting magnetic-resonance signals from the test matter and digitizing the signals to form digitized magnetic-resonance signals;

(e) a digitized-signal averager/processor connected to the receiver/digitizer for accumulating and storing digitized magnetic-resonance signals from the receiver/digitizer and digitally processing the stored signals for interpretation and display, processing operations carrier out by the averager/processor being specified by control signals applied to the averager/processor;

(f) a programmable instrument controller having measurement-sequence control-program storage for storing a plurality of measurement-sequence control programs, each measurement-sequence control program specifying one of the plurality of magnetic-resonance measurement sequences which the magnetic-resonance instrument is programmable to perform and being associated with a digital control-program identifier for identifying the measurement-sequence control program, the instrument controller being adapted to recall and execute selectively a measurement-sequence control program identified by a specified control-program identifier to generate control signals for the magnetic-resonance measurement sequence specified by the control program, the instrument controller being connected to the radio-frequency generator/transmitter for applying control signals to the generator/transmitter to specify the timing of the radio-frequency excitation signals generated by the generator/transmitter and connected to the digitized-signal averager/processor for applying control signals to the averager/processor to specify processing operation carried out by the averager/processor;

(g) a barcode reader connected to the instrument controller for reading barcode-encoded data words and transmitting signals representative of the data words to the instrument controller, a plurality of barcode-encoded data words defining measurement-sequence data words, one or more barcode-encoded data words being associated with each of the magnetic-resonance measurement sequences which the magnetic-resonance instrument is programmable to perform to constitute measurement-sequence specification information sufficient to specify the measurement sequence at least to the extent of permitting the control-program identifier associated with a measurement-sequence control program which specifies the

measurement sequence to be identified, the instrument controller being adapted to receive signals from the barcode reader representative of the one or more barcode-encoded measurement sequence data words which constitute measurement-sequence specification information specifying a measurement sequence and to recall and execute the measurement-sequence control program identified by the control-program identifier identified in the measurement-sequence specification information; and

(h) at least one measurement-sequence-selection barcode table having a plurality of barcode-encoded measurement-sequence data words arranged on it, each barcode-encoded measurement-sequence data word on the barcode table being selectively readable by a user with the barcode reader to transmit signals to the instrument controller representative of the measurement-sequence data word, the measurement-sequence-selection barcode table having a plurality of measurement sequences associated with it which the magnetic-resonance instrument is programmable to perform, each of the measurement sequences associated with the barcode table being specifiable by magnetic-sequence specification information constituted by one or more of the barcode-encoded measurement-sequence data words included on the barcode table, so that a user can cause the magnetic-resonance instrument to selectively perform a magnetic-resonance measurement sequence specified by one of the measurement-sequence control programs associated with the measurement-sequence selection barcode table by reading a corresponding one or more of the barcode-encoded measurement-sequence data words on the measurement-sequence-selection barcode table with the barcode reader.

2. The magnetic-resonance instrument according to claim 1 in which the barcode reader is a hand-holdable barcode-reader wand connected to the instrument controller by means of a flexible signal-transmission cable.

3. The magnetic-resonance instrument according to claim 2 in which the magnetic-resonance instrument includes a console having a control panel, the barcode-reader wand being connected to the console by the signal-transmission cable and the measurement-sequence-selection barcode table being removable mountable on the control panel at a location where the barcode-encoded measurement-sequence data words arranged on the barcode table may be read by the barcode reader wand.

4. The magnetic-resonance instrument according to claim 3 in which the coupling circuitry of the probe comprises a replaceable element, the replaceable element being labelled with a barcode-encoded part-identification code for identifying the element, the instrument controller being adapted to receive signals from a barcode reader representative of the part-identification code and to condition performance of a measurement sequence upon verification that the signals represent a replaceable element acceptable for the measurement sequence.

5. The magnetic-resonance instrument according to claim 3 in which the instrument is a pulse/Fourier-transform NMR spectrometer.

6. The magnetic-resonance instrument according to claim 3 in which the instrument is a magnetic-resonance tomographic imaging device.

7. A magnetic-resonance spectrometer programmable to perform a plurality of magnetic-resonance measurement sequences, comprising:

(a) a magnet for generating a substantially homogeneous magnetic field;

(b) a probe having radio-frequency coupling circuitry positionable in the magnet for positioning a sample to be analyzed in the magnetic field and for coupling radio-frequency signals between the sample and the coupling circuitry;

(c) a radio-frequency generator/transmitter connected to the coupling circuitry of the probe for generating and amplifying radio-frequency excitation signals in accordance with a magnetic-resonance measurement sequence for exciting magnetic-resonance signals from the sample in the probe, the timing of the excitation signals being specified by control signals applied to the generator/transmitter;

(d) a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe for amplifying and detecting magnetic-resonance signals from the sample to be analyzed in the magnetic field and for coupling radio-frequency signals between the

sample and the coupling circuitry;

(c) a radio-frequency generator/transmitter connected to the coupling circuitry of the probe for generating and amplifying radio-frequency excitation signals in accordance with a magnetic-resonance measurement sequence for exciting magnetic-resonance signals from the sample in the probe, the timing of the excitation signals being specified by control signals applied to the generator/transmitter;

(d) a radio-frequency receiver/digitizer connected to the coupling circuitry of the probe for amplifying and detecting magnetic-resonance signals from the sample and digitizing the signals to form digitized magnetic-resonance signals;

(e) a digitized-signal averager/processor connected to the receiver/digitizer for accumulating and storing digitized magnetic-resonance signals from the receiver/digitizer and digitally processing the stored signals for interpretation and display, processing operations carried out by the averager/processor being specified by control signals applied to the averager/processor;

(f) a programmable spectrometer controller having measurement-sequence control-program storage for storing a plurality of measurement-sequence control programs, each measurement-sequence control program specifying one of the plurality of magnetic-resonance measurement sequences which the spectrometer is programmable to perform and being associated with a digital control-program identifier for identifying the measurement-sequence control program, the spectrometer controller being adapted to recall and execute selectively a measurement-sequence control program identified by a specified control-program identifier to generate control signals for the magnetic-resonance measurement sequence specified by the control program, the spectrometer controller being connected to the radio-frequency generator/transmitter for applying control signals to the generator/transmitter to specify the timing of the radio-frequency excitation signals generated by the generator/transmitter and connected to the digitized-signal averager/processor for applying control signals to the averager/processor to specify processing operations carried out by the averager/processor;

(g) a barcode reader connected to the spectrometer controller for reading barcode-encoded data words and transmitting signals representative of the data words to the spectrometer controller, a plurality of barcode-encoded data words defining measurement-sequence data words, one or more barcode-encoded data words being associated with each of the magnetic-resonance measurement sequences which the spectrometer is programmable to perform to constitute measurement-sequence specification information sufficient to specify the measurement sequence at least to the extent of permitting the control-program identifier associated with a measurement-sequence control program which specifies the measurement sequence to be identified, the spectrometer controller being adapted to receive signals from the barcode reader representative of the one or more barcode-encoded measurement sequence data words which constitute measurement-sequence specification information specifying a measurement sequence and to recall and execute the measurement-sequence control program identified by the control-program identifier identified in the measurement-sequence specification information; and

(h) at least one measurement-sequence-selection barcode table having a plurality of barcode-encoded measurement-sequence data words arranged on it, each barcode-encoded measurement-sequence data word on the barcode table being selectively readable by a user with the barcode reader to transmit signals to the spectrometer controller representative of the measurement-sequence data word, the measurement-sequence-selection barcode table having a plurality of measurement sequences associated with it which the spectrometer is programmable to perform, each of the measurement sequences associated with the barcode table being specifiable by magnetic-sequence specification information constituted by one or more of the barcode-encoded measurement-sequence data words included on the barcode table, so that a user can cause the spectrometer to selectively perform a magnetic-resonance measurement sequence specified by one of the measurement-sequence control programs associated with the measurement-sequence selection barcode table by reading a corresponding one or more of the barcode-encoded measurement-sequence data words on the measurement-sequence-selection barcode table with the barcode reader.

8. The magnetic-resonance spectrometer according to claim 7 in which the barcode reader is a hand-holdable barcode-reader wand connected to the instrument controller

by means of a flexible signal-transmission cable.

9. The magnetic-resonance spectrometer according to claim 8 in which the magnetic-resonance spectrometer includes a console having a control panel, the barcode-reader wand being connected to the console by the signal-transmission cable and the measurement-sequence-selection barcode table being removably mountable on the control panel at a location where the barcode-encoded measurement-sequence data words arranged on the barcode table may be read by the barcode reader wand.

10. The magnetic-resonance spectrometer according to claim 9 in which the instrument is a pulse/Fourier-transform NMR spectrometer.

End of Result Set

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L34: Entry 1 of 1 File: USPT Nov 7, 1995

DOCUMENT-IDENTIFIER: US 5465361 A
TITLE: Microcode linker/loader that generates microcode sequences for MRI sequencer by modifying previously generated microcode sequences

Abstract Text (1):
An extremely fast and efficient Linker for a Magnetic Resonance Imaging (MRI) system Nuclear Magnetic Resonance (NMR) pulse control sequencer efficiently derives subsequent blocks of microcode to be loaded by using the contents of a memory buffer containing previously loaded microcode as a template, Most of the template is reused "as is". Only the relatively few field values in the microinstructions which change from one signal generation process, or cycle, to the next are replaced with new values. Offsets are tabulated of instructions which have associated multi-entry cycle indexed program change table (PCT) values. When further code is to be linked and loaded, the linker accesses the PCTs based on the table and to inserts new values into the appropriate instruction fields. The microcode memory image may be continuously maintained in a host memory buffer and re-edited successive times. The Fast Linker provided by the present invention is capable of continually loading microcode into a sequencer writable control store, and is fast enough to run under a time shared operating system at the same time a higher priority data acquisition and display process is executing.

Brief Summary Text (3):
Ser. No. 07/551,798 of Hoenninger filed 12 Jul. 1990 entitled "MAGNETIC RESONANCE IMAGING SEQUENCER GATING" now issued U.S. Patent No. 5,291,610 (Attorney Docket 89-39);

Brief Summary Text (4):
Ser. No. 08/032,647 of Hoenninger filed 17 Mar. 1993, entitled "CONTROL INTERFACE FOR AN NMR SYSTEM" (Attorney Docket No. 89-59); and

Brief Summary Text (5):
Ser. No. 07/571,258 of Zeilenga et al filed 23 Aug. 1990 entitled "CONTINUALLY LOADABLE MICROCODE STORE FOR MRI CONTROL SEQUENCERS" (Attorney Docket No. 89-108) now issued U.S. Pat. No. 5,144,242.

Brief Summary Text (7):
This invention relates to nuclear magnetic resonance (NMR) techniques and more particularly to magnetic resonance imaging (MRI). Still more particularly, the present invention relates to microcoded pulse sequence generators (so-called "sequencers" or "pulse programmers") for MRI equipment. In still more detail, the present invention relates to a process for machine generating machine-executable state-change instructions for the sequence controller of a multi-slice magnetic resonance imaging system and to an arrangement for rapidly and efficiently linking microcode for such a sequence controller.

Brief Summary Text (9):
The fundamentals of the MRI experiment are well known. Briefly (and hopefully without undue oversimplification), in a typical MRI system an object 10 (see FIG. 2) to be imaged (e.g., a portion of the human body) is placed in an external static magnetic field gradient. Protons within the object tend to align their spins in accordance with the magnetic field direction. The object is excited by one or more RF excitation pulses of appropriate frequency, timings and durations (as one example, so-called "spin-echo" type pulse sequences may be used). The RF excitation pulses generated at the Larmour frequency cause the protons to precess their spins.

When each RF pulse is switched off, the nuclei precess back toward their equilibrium position and in this relaxation process emit an NMR response that can be detected by an RF receiver.

Brief Summary Text (10):
As is well known, different pulse sequences can be used to obtain different results. A pulse sequence generator (hereafter "sequencer") portion of the system (e.g., often a high-speed hardware state machine based on a bit slice processor architecture) provides the sequence of control signals that controls the operation of the RF transmitter(s), RF receiver(s) and gradient magnet(s). The sequencer must reliably provide a high degree of flexibility (e.g., to provide generation of different desired pulse sequences) as well as adequate time resolution and other important features.

Brief Summary Text (11):
The following is a non-exhaustive listing of possibly representative prior patents and articles relating to NMR sequencers:

Brief Summary Text (16):
Conway et al, "Circuit for A Digital Pulse Programmer," 48 Rev. Sci Instrum., No 6, p. 656 (Jun. 1977);

Brief Summary Text (17):
Caron, "A New Programmable Timer Designed for Pulsed NMR," 31 Journal of Magnetic Resonance, p. 357 (1978);

Brief Summary Text (18):
Case et al, "Versatile Pulse Sequence Generator for Pulse NMR," 35 Journal of Magnetic Resonance, p. 439 (1979);

Brief Summary Text (19):
Dart, "Highly Flexible Pulse Programmer for NMR Applications," 51 Rev. Sci. Instrum., No 2, p. 224 (February 1980);

Brief Summary Text (20):
Thomann et al, "Digital Pulse Programmer for An Electron-Spin-Resonance Computer-controlled Pulsed Spectrometer," 55 Rev. Sci. Instrum., No 3, p. 389 (March 1984);

Brief Summary Text (21):
Jensen et al, "A Universal Pulse Programmer for NMR Imaging," Proceedings for the Third Annual SMRM, p. 379 (1984);

Brief Summary Text (22):
Sidky et al, "State-machine Digital Pulse Generator," 59 Rev. Sci. Instrum., No 5, p. 806 (May 1988); and

Brief Summary Text (24):
As described in some of the documents listed above, a sequencer may comprise a microcoded sequential state machine, with each different state providing different output control signals to control different portions of the NMR equipment (e.g., RF transmitter and receiver, gradient coils, etc.). The "next state" to which the sequencer transitions is typically determined by the sequencer previous state. The time at which such a transition occurs is generally variable (since different NMR equipment "states" last for different durations within a typical NMR pulse sequence) and typically may also be determined by the previous state. Different microcode may by loaded into a control store (WCS) within the sequencer to define different pulse sequences.

Brief Summary Text (25):
Thus, MRI microcoded sequencers generally include a writable control store (WCS) containing a sequence of microinstructions that define a corresponding sequence of machine states. The microinstructions are, in one sense, a computer program executed by the sequencer. This microcode computer program specifies sequencer outputs (e.g., to control portions of the MRI system such as the RF transmitter, the gradient coils, etc.) and also specifies the duration of such sequencer outputs. In addition, the microcode specifies an ordered sequence of sequencer machine states--by providing a corresponding ordered "in line " sequence of microinstructions executed one after another (e.g., in the order in which the microinstructions are stored in

the control store) and/or by providing conditional or unconditional "branching" microinstructions which cause particular microinstruction(s) to be performed in an order different from the order in which the microinstructions are stored in the control store.

Brief Summary Text (26):
Since the sequencer control store is writable (e.g., by a host computer linked to the sequencer), different NMR pulse sequences can be specified by simply downloading different microinstructions into the sequencer control store. Thus, different microinstruction sequences corresponding to hundreds of different NMR pulse sequences may be maintained on the host computer's mass storage (e.g., hard disk). Briefly, software executing on the host computer permits an operator to select (or create) particular sequencer microcode routines corresponding to particular experiments. The host computer then "links" and downloads the selected ("main") routines into the sequencer writable control store for execution by the sequencer. The host computer may download, along with the actual microcode routines, additional routines and data (e.g., commonly used subroutines, reference tables and the like) that must be present in the writable control store (and linked with the main routines) in order for the selected microcode routines to run.

Brief Summary Text (27):
U.S. Pat. No. 4,707,661 to Hoenninger, III et al (1987) (hereafter "Hoenninger '661") describes a highly successful technique for efficiently generating sequencer state change microinstructions. The entire disclosure (including the FIGURES) of Hoenninger '661 are hereby expressly incorporated herein by reference. The preferred embodiment Fast Linker disclosed and claimed in the subject application is an extension of the prior Linker design disclosed in Hoenninger '661. The following discussion briefly summarizes some (although not all) of the more important details disclosed in the Hoenninger '661 patent that relate to the arrangement disclosed and claimed in the subject application. The reader is referred to that prior Hoenninger '661 patent for additional details relating to that prior art microcode generation technique.

Brief Summary Text (28):
As is well known, the term "linker" or "link editor" as used in computer science typically refers to a program (or system) that resolves cross references (e.g., "external" references to "global" variables shared among several different programs and/or subroutines, address references permitting a one routine to call another routine, etc.) between routines (and subroutines) that have been assembled or compiled separately. A "linking loader" resolves such cross-references and loads the "linked" programs and subroutines into memory for execution. Although the microcode Linker/Loader described in the Hoenninger '661 patent resolves cross references, it performs many other tasks and functions (e.g., handling of external loop specifications and directives) that are generally non-analogous to non-MRI Linker functions.

Brief Summary Text (29):
Hoenninger '661 describes the use of program change tables (hereafter referred to as "PCTs") combined with techniques for grouping and replicating program segments with indexed symbolic addresses to greatly reduce the number of lines of microcode that must be written for a typical MRI sequence.

Brief Summary Text (30):
This earlier described technique relies upon a decomposition of MRI sequences into such program code "templates" (i.e., program segments) which encode the unique sequence of machine states required for only one set of spin echoes for one slice. The code templates are then logically associated with program change tables (PCTs) comprising lists of parameter values which may then be arbitrarily specified for any field in a line of microcode. This association permits a multiplicity of template implementations to be generated in a completely predictable way. Hoenninger '661 thus teaches that instead of generating each slice-specific portion of sequencer microcode independently, it is possible (due to the high degree of redundancy and similarity in MRI sequencer microcode from one program segment to the next) to replicate entire blocks of microcode based on a more general model or "template" of the microcode--and to merely replicate microcode program segments (with altered MRI parameter values and addresses as appropriate) to provide appropriate additional slice-specific program segments. Hoenninger '661 teaches embedding symbolic reference pointers within the template to refer to parameter values to be obtained externally from PCTs, but also recognizes that the parameter values themselves can

be utilized and simply changed from one execution pass to the next.

Brief Summary Text (31):
The MRI Linker described in Hoenninger '661 accepts an "Linker Control Statement" as an input data string. The Hoenninger '661 patent describes the general format of such an input data string. This input data string is parsed to extract main routine and subroutine entries, and to ascertain table identifications and ranges corresponding to slice-specific entries. The microcode is generated in response to such Linker statements.

Brief Summary Text (32):
Slice-specific program segments cannot simply be re-executed for different slices because of the different parameters which vary from one slice to the next. Hoenninger '661 teaches replicating such slice-specific program segments by: (a) changing slice-specific parameter values as may be required for specific slices, and (b) appropriately indexing symbolic address arguments associated with "jump to subroutine" or "jump" instructions as well as the symbolic address(es) of the associated slice-specific program segments. Other program segments (e.g., those associated with sampling) are not replicated but are instead simply stored once at a predetermined place in memory and accessed (e.g., as a subroutine) by a fixed symbolic address at any point in the program.

Brief Summary Text (33):
During execution of the Linker program, any encountered subroutines that are not slice-specific are treated as true subroutines which are not replicated. On the other hand, all program segments designated as being "slice-specific" are replicated in a predetermined order (as specified by the input Linker Control Statement)--while indexing the corresponding symbolic addresses associated with the replicated program segments and also indexing the appropriate referenced PCT entries in a predetermined sequence so as to maintain proper correspondence between slice-specific main programs and subroutines in each replicated segment.

Brief Summary Text (34):
FIGS. 6A-6C of Hoenninger '661 illustrate exemplary "Linker" program control steps for generating microcode using the program change tables and templates mentioned above. These FIGURES are set forth herein as prior art FIGS. 1A-1C.

Brief Summary Text (35):
Briefly, after entering the Linker Program at 600 (where a "cycle" counter may be set to a content of "1"--this cycle counter keeping track of "phase encoding cycles" as will be understood by those skilled in this art), the slice-specific routines are expanded at 604 by (a) replicating slice-specific segments appearing within parentheses in an indicated order using indexed symbolic addresses and indexed parameters from the referenced PCTs (program change tables), and (b) not replicating subroutine segments not within the parentheses of the slice-dependent portion of the inputted linker control statement and also not indexing certain symbolic addresses associated with this subset of subroutines. In addition, the Linker of FIGS. 1A-1C expands slice-specific main program segments appearing within parentheses of the Linker Control Statement at 606 in a predetermined order (e.g., as specified by the syntax of the Linker Control Statement) using indexed symbolic addresses and indexed parameters from referenced PCTs (except for the predetermined subset of non-slice-specific subroutine segment references which are related as true and conventional subroutines without indexed symbolic addresses). Other program segments designated in the Linker Control Statement are also appropriately linked before the cycle counter is tested. Unless the last cycle has been linked, the cycle counter is incremented and the main program base memory location is updated and control is passed back to the beginning of routine 606. Once microcode for the last cycle of operation has been properly linked, the control is passed to block 614 where the final line of microcode is generated including a "stop" code, and an exit is taken from the Linker Program at block 616 (whereupon the generated microcode may be loaded and executed if desired).

Brief Summary Text (36):
The Linker described in the Hoenninger patent has (e.g., due to it high efficiency and speed) been highly successful in its own right. However, further improvements are possible. For example, it has become highly desirable to provide even more efficient and rapid linking of MRI sequence controller microcode than is provided by the Linker described in Hoenninger '661.

Brief Summary Text (37):
FIG. 1D describes an exemplary prior art sequencer microcode reloading technique used in the past in conjunction with the Liner described in Hoenninger '661. At block A (before the sequencer is started), the host computer links and loads the entire control store with micro-instructions (e.g., by performing the program control instructions shown in prior art FIGS. 1A-1C). When the sequencer is started (blocks B and C), the sequencer repetitively reads from the control store and executes the micro-instructions stored within the store--thus generating NMR pulse sequences for a desired NMR experiment. In more complex experiments the sequencer will reach the end of the control store before the experiment has terminated ("Y" exit of decision block C) and require micro-instructions that are not yet resident in the store. When the sequencer reaches the end of the control store, it suspends operations momentarily (block D) and requests the host to rewrite the control store. The host links an entire new sequencer control store-sized block of microcode (e.g., once again performing all of the instructions set forth in routine 606 shown in FIGS. 1A-1C, the symbol tables and PCTs generated by routine 604 preferably being retained by the host from before; block E) while the sequencer is executing the previously loaded microcode. It begins loading the sequencer memory as soon as it is requested to do so if linking has been completed, otherwise loading is delayed.

Brief Summary Text (38):
The sequencer can be designed so that the host can very rapidly load the writable control store (e.g., using direct memory access (DMA) techniques). Rewriting the control store at block E may thus introduce less than a one second delay if linking is completed when the sequencer requests reloading. Once the host has successfully rewritten the sequencer control store, the sequencer may resume operations at the beginning of the control store (or at some other predetermined transfer point) (block F). The writable control store can be reloaded as many times as necessary to cause the sequencer to execute the entire control program.

Brief Summary Text (39):
Unfortunately, this FIG. 1D technique generates some significant problems in the real time control context of an NMR sequencer. The regular RF stimulations provided during MRI imaging cause the NMR-sensitive molecules within the body being imaged to enter a dynamic steady state different from the unexcited steady state. If these regular stimulations are interrupted, relaxation causes the NMR-sensitive molecules to move away from the dynamic steady state toward their natural (unexcited) steady state. Interrupting the NMR pulse sequence to link microcode and reload the writable control store interrupts the regular stimulations.

Brief Summary Text (40):
A technique known as "spin conditioning" has been used to stimulate the body back to dynamic steady state after such an interruption (and before data acquisition resumes). However, spin conditioning wastes time and may also not be entirely effective in avoiding image degradation caused by the interruption. This is due to the fact that the exponential time constants of the spins in some human body tissues are 1-2 seconds and spin conditioning is not usually performed for the 5-10 seconds required to return to steady state. There may also be eddy currents in the magnet with time constants in excess of 1 second. Since the time between reloads of the control store is constant in most cases, the disruption is periodic and the Fourier Transform of the resulting data is sensitive to this periodic perturbation of the data, resulting in image artifacts. A disruption near the zero phase encoding data acquisition will cause especially strong effects. Interruption due to control store loading should be avoided in order to prevent loss of steady state in the body which can lead to artifacts and noise in the acquired image data-- and thus cause image degradation.

Brief Summary Text (41):
Copending, commonly-assigned application Ser. No. 07/571,258 of Zeilenga et al entitled "Continuously Loadable Microcode Store for MRI Control Sequencers" (attorney docket no. 89-108), now issued U.S. Pat. No. 5,144,242 describes an MRI pulse sequencer which permits microcode to be continually loaded substantially without interruption of MRI pulse sequences being generated by an associated MRI system--thus avoiding the image degradation and other problems resulting from interrupting the NMR pulse sequence to load microcode. However, the availability of a continually loadable MRI microcoded sequencer introduces speed and other requirements that may not be fully satisfied by the Linker described in the Hoenninger '661 patent.

Brief Summary Text (42):
It would be possible to use the Linker earlier described in the Hoenninger '661 patent to link and store (e.g., on mass storage) all of the required sequencer microcode ahead of time--and to then simply load the pre-generated microcode from memory and/or mass storage as required. Unfortunately, such an arrangement would require a great deal of latent processing time between user inputting of a "link and load" command and the actually beginning of sequencer execution. In order to increase overall MRI system throughput and flexibility, it would be highly desirable to drive such a continually loadable sequencer with a host processor that is capable of continually generating microcode "on the fly" for loading into the sequencer. Thus, it would be desirable for the host processor to be capable of rapidly linking and loading replacement pages of sequencer microcode in real time as needed, where the link time is always less than the execution time of a page of microcode. Through such cooperation between a continually loadable sequencer and a linker continually generating microcode, it would be possible to provide NMR pulse sequences of arbitrarily long duration without interruption--and without long startup latency.

Brief Summary Text (43):
One possible technique to accomplish such continual microcode linking is to execute the Linker of the type described in the Hoenninger '661 patent with a host processor that has sufficient processor resources dedicated to the linking function. However, relatively modest minicomputers are not capable of generating, linking and loading microcode at a sufficiently rapid rate to keep up with a continually loadable sequencer in the case of the fastest sequences.

Brief Summary Text (44):
It is also a design goal to eliminate the extra cost and added complexity of a dedicated linker processor. State-of-the-art MRI system design has moved towards a single processor architecture. In such a single processor architecture, a single main processor (e.g., a minicomputer) performs all data processing functions associated with data acquisition, reconstruction and display--as well as all data processing functions associated with microcode linking and loading (and other sequencer support). Unfortunately, data acquisition, reconstruction and display tasks are extremely processor intensive. The processor-intensive Linker described in the Hoenninger '661 patent cannot be efficiently, timely executed on a continual basis by a cost-effective host processor also engaged in simultaneous data acquisition and display (at least using current cost-effective minicomputer technology).

Brief Summary Text (45):
During the time the sequencer is operating, the host processor is busy acquiring data in real time (and generally also reconstructing and preferably displaying images). There are generally few processor resources left over for performing functions such as microcode linking. To be successful in such a host computer multitasking environment, a microcode linker/loader must place only minimal demands on the host processor during the time data is being acquired and/or displayed--while nevertheless still being capable of continually generating an arbitrary amount of microcode "on the fly" in real time so as to permit sequencer reloading while the sequencer is running.

Brief Summary Text (46):
The present invention provides an extremely fast and efficient microcode Linker that exerts minimal demands on the host processor once data acquisition has begun.

Brief Summary Text (47):
An important feature of the Fast Linker provided by the present invention is the use of memory image templates which can be efficiently constructed given the large amount of the microcode which is static from one signal generation process to the next. The collection of data for an MRI image is essentially the collection of an interference pattern which is generated by performing successive sequences of operations on the spin lattice in the object being imaged. Each sequence of operations is very similar to the previous one. This fact is exploited to create sequencer memory image templates which can be linked before loading simply by inserting (changing) the relatively few microcode field values in the instructions of the sequence which change from one signal generation process, or cycle, to the next. A cycle of microcode in the present invention typically may control the generation of all spin echo signals for all slices for a single phase encoding value.

Brief Summary Text (48):
Briefly, the Linker provided by the present invention generates an initial block ("template") of microcode in a more efficient manner in accordance with the steps shown in prior art FIGS. 1A-1C (and in the manner disclosed in the prior issued Hoenninger '661 patent). This initial block of microcode is stored in a memory buffer, and may be downloaded into the microcoded sequencer at an appropriate time. The Fast Linker provided by the present invention provides a highly efficient technique for deriving subsequent blocks of microcode by using the contents of the memory buffer as a template, by changing only those few values that need to be changed, and by reusing most of the template "as is" for reloading the sequencer memory.

Brief Summary Text (49):
The size of the microcode set for a cycle is determined by the number of instructions in the main routines of the sequence. Typically, the MRI control store is large enough to contain many cycles of microcode. A table is constructed at the time the microcode template is created in the load buffer which records the offsets of all instructions which have associated multi-entry cycle indexed program change table (PCT) values. When further code is to be linked and loaded, the only operation necessary before loading is to access the PCTs in a sequence data base based on the list in the table and to then insert the values so obtained into the appropriate instruction fields.

Brief Summary Text (50):
For example, to create a subsequent block of microcode, the initially-created microcode memory image may be edited to generate further microcode to be downloaded into the sequencer control store. Such "editing" does not need to edit addresses in the preferred embodiment--since in accordance with a further feature of the present invention, the edited image is written into the same area of the sequencer control store memory space the initially generated block was loaded into (and the addresses set forth in the microcode block may thus stay constant from one loading to the next). Rather, within the memory buffer only certain (e.g., phase encoding cycle-specific) values such as jump limits, clock times, gradient values are changed to generate a subsequent block of microcode.

Brief Summary Text (51):
Such limited editing of the existing microcode memory image can be performed extremely rapidly and efficiently by the host processor. The preferred embodiment provides efficient means (e.g., a tabular pointer and offset arrangement) to keep track of the information that must be changed to produce a subsequent page of microcode, and new values to be inserted into the memory image can be efficiently obtained from PCTs (program change tables) of the type described in the prior-issued Hoenninger '661 patent.

Brief Summary Text (52):
In the preferred embodiment, the microcode memory image may be continuously maintained in a host memory buffer and re-edited successive times (each time replacing the same limited set of old cycle-specific values with a new set of values) such that the host computer only needs to maintain a single copy of the microcode memory image for each memory page. Further efficiency is gained by repetitively editing the same microcode memory image in place and then downloading the edited memory image directly from the memory buffer to the sequencer (thus avoiding copying from one memory buffer to another and avoiding copying between mass storage and memory).

Brief Summary Text (53):
Continual linking and loading of the sequencer microcode control store when the sequencer is running ensures that the sequencer outputs are not interrupted even though the control store is not large enough to store all of the microcode needed to execute an MRI sequence. The Fast Linker provided by the present invention is capable of continually loading a sequencer writable control store and is fast enough to run under a time shared operating system at the same time a higher priority data acquisition and display process is executing. The preferred embodiment Fast Linker is (as one example) quick enough on the MicroVAX II (about 100 ms per 1024 lines of microcode linked when running as the sole process) that it does not have to run as a "time critical" process (which greatly improves the performance and responsiveness of the overall MRI system). This speed also allows fast continuous sequences which generate, reconstruct and display an image periodically (e.g., every 1 sec) for long periods of time to run successfully on a MicroVAX II (which provides a relatively

modest CPU throughput less than 1 Mips).

Drawing Description Text (3):
FIGS. 1A, 1B, 1C, and 1D are schematic diagrams in flowchart form of the microcode reload operation performed by an exemplary prior art NMR microcoded pulse sequencer;

Drawing Description Text (4):
FIG. 2 is a high level block diagram of a presently preferred exemplary embodiment of an NMR system including a host processor with an improved Linker provided by the present invention;

Drawing Description Text (6):
FIG. 4 is a schematic flowchart of exemplary program control steps performed by the host processor shown in FIG. 2;

Drawing Description Text (8):
FIGS. 6A, 6B, 6C, 6D, 6E, and 6F are more detailed flowcharts of program control steps performed by the host processor shown in FIG. 2;

Drawing Description Text (9):
FIGS. 7A, 7B, and 7C are schematic diagrams of exemplary data structures used by the FIG. 2 host processor;

Detailed Description Text (2):
The overall architecture of a preferred embodiment NMR system 100 will first be described in conjunction with FIG. 2. Then, a high level description of a sequence of host computer operations used to provide fast linking of the microcode will be discussed in conjunction with FIGS. 3A-3D, 4 and 5A-5B. Following such discussion, a more detailed description of the presently preferred exemplary embodiment fast microcode linker will be presented in conjunction with FIGS. 6-7. Finally, a brief discussion of a suitable microcoded sequencer for use with the preferred embodiment Linker will be provided in connection with FIGS. 8-9.

Detailed Description Text (3):
I. Overall NMR System 100

Detailed Description Text (4):
The block diagram of FIG. 2 depicts the general architecture of an exemplary preferred NMR imaging system 100 of the type with which the microcode sequencer with continually loadable microcode store in accordance with the present invention may be used.

Detailed Description Text (5):
Typically, a human or animal subject (or any other object to be imaged) 10 is: placed within a static magnetic field. For example, the subject may lie along the z-azis of a static magnet 108 which establishes a substantially uniform magnetic field directed along the z-azis within the portion of the object 10 of interest. For example, contiguous parallel slice-volumes p,q . . . z may be located within the volume to be imaged. Gradients (e.g., a fixed weak z gradient) may be imposed within this z-axis directed magnetic field along mutually orthogonal x,y,z axes by a set of x,y,z gradient amplifiers and coils 114 to phase encode the resulting NMR response signals which are generally then read out with the gradients turned off. NMR RF signals are transmitted into the object 10 and NMR RF responses are received from the object via RF coils 116 connected by a conventional transmit/receive switch 118 to an RF transmitter 120 and RF receiver 122. As will be appreciated by those in the art, separate transmit and receive coils may be used in some installations, in which case the T/R switch 118 may not be needed.

Detailed Description Text (6):
All of the prior mentioned elements may be controlled, for example, by a microcoded control sequencer 140 which communicates with a data acquisition and display computer (hereafter "host processor") 126 (which includes a random access memory 127 along with various other conventional components as is well known). The latter host processor 126 may receive NMR responses via an analog-to-digital converter 128, analyze the received responses, and generate images of body 10 in real time. A CRT display and keyboard unit (terminal) 130 is typically also associated with the host processor 126.

Detailed Description Text (7):
As will be apparent to those in the art, such an arrangement may be utilized to generate desired sequences of magnetic gradient pulses and NMR RF pulses and to measure the desired NMR RF responses in accordance with stored computer programs.

Detailed Description Text (8):
In particular, host processor 126 maintains, on mass storage, a library of microcode routines corresponding to useful NMR pulse sequences. An operator may select (and also edit or otherwise manipulate) desired microcode routines from the library via terminal 130, and then command host processor 126 (e.g., by inputting "Linker Control Statements" via terminal 130) to assemble and link such microcode routines and load the resulting executable microcode into sequencer 140 for execution by system 100. The sequencer 140 controls, in real time, the gradient amplifiers and coils 114, the RF receiver 122 and the RF transmitter 120, so as to cause NMR pulse sequences to be generated. Host computer 122 receives the digitized RF NMR responses (via A/D converter 128) and processes those digitized responses (e.g., via image reconstruction and other conventional techniques) so as to provide, on terminal 130 (or other display), one or more images corresponding to body 10.

Detailed Description Text (10):
FIGS. 3A-3D are a sequence of schematic block diagrams which graphically illustrate the continual linking and loading of microcode for the FIG. 2 host processor 126 in cooperation with sequencer 140.

Detailed Description Text (11):
Referring to FIGS. 3A and 4 together, a human operator first selects the particular NMR pulse sequences to be performed by system 100 (e.g., by interacting with a menu driven software selection routine via terminal 130 to provide a Linker Control Statement) (FIG. 4, block 200). In response to such selections, host computer 126 retrieves one or more corresponding microcode routines and subroutines from mass storage and also retrieves tables and other data/routines required for execution of the retrieved routines.

Detailed Description Text (12):
When the human operator requests system 100 to link and load the selected microcode routines, host processor 126 links the initial routine(s) and subroutine(s) with tables, etc. more or less in accordance with the program control steps of routines 604, 606 shown in prior art FIG. 1A-1C (with some differences, i.e., generating microcode page templates and an instruction offset table PCTTBL, as will be explained shortly)--continuing this linking process until a first page (16K micro-instructions long or less in the preferred embodiment) of linked microcode has been generated and stored in a Page 0 host memory buffer 232 within host computer memory 127 (FIG. 4, block 202). At this point Page 1 host memory buffer 234 contains a microcode template if more than one page of microcode is required for the sequence. Host processor 126 then sets a page indicator pointer (PI) to indicate sequencer control store Page 0 (for example) (block 204) and downloads this first page worth of microcode (including the associated subroutines, etc.) from memory buffer 232 into WCS 150 Page 0 using direct memory access (DMA) techniques (block 206; see FIG. 3A).

Detailed Description Text (15):
The next to last instruction 265 is either a STOP instruction; or an instruction that has the effect of allowing sequencer 140 to jump to the bottom of the other page of writable control store 150. In the preferred embodiment, a conditional branch instruction 265 causes the sequencer 140 to test the setting of a sequencer control status register condition bit. The sequencer control status register contains a bit indicating whether host processor 124 is currently writing to the other page. The effect of the instruction 265 is to prevent sequencer 140 from jumping to the page of writable control store 150 being written by host processor 124--and to stop the sequencer and generate an error if this ever occurs by continuing to STOP instruction 266.

Detailed Description Text (17):
In conventional multi-slice MRI systems, multiple slices are typically imaged in rapid sequence (with the slice sequence being sufficiently long in duration to permit T.sub.1 relaxation to occur before the same slice is excited again). A given cycle section 269 includes such a sequence of multiple slice sections 271(1)-271(N).

Detailed Description Text (18):
In the preferred embodiment, different cycle sections 269 correspond to different phase encodings to be collected. As is well known, phase encoding is typically used to encode spatial information in one or more (e.g., two) directions so as to obtain multi-dimensional (e.g., 2-D or 3-D) images. Phase encoding involves gradually changing one or more gradients during a scan to provide, for the same slice-volume, different gradient values in one or more directions.

Detailed Description Text (19):
In the preferred embodiment, all of slice sections 271(1)-271(N) within cycle section 269 (1) are encoded with the same phase encoding parameters--such that cycle section 269(1) includes microinstructions for each slice to be imaged and specifying the same phase encoding values. A further cycle section 269(2) of microcode includes slice sections 273(1)-273(N) corresponding to slice 271(1)-271(N), respectively; but the slice sections within cycle section 269 include different phase encoding values (specifying a different phase encoding from the one specified by the first cycle section 269(1)). In general, the principal differences between the microcode specified within cycle section 269(1) and the microcode within cycle section 269(2) is the different phase encoding values (i.e., X gradient value, Y gradient value and/or Z gradient value; excitation time duration values; etc.). Of course, there typically also are differences in the JUMP and BRANCH addresses specified in different cycle sections 269 due to the different areas of memory in which those cycle sections are stored.

Detailed Description Text (21):
The illustrated slice section 271(J) includes microinstructions 275(1)-275(N), each of which may include various microinstruction fields (e.g., op code field, clock time field, system control fields, a wait field, etc.) as illustrated in FIG. 5B. Microinstruction 275(2) shown in FIG. 5B includes, for example, a "Jump Limit" microinstruction field 277. Microinstruction 275(3) includes a "clock time" microinstruction field 279. Microinstruction 275(5) shown in FIG. 5B includes an X gradient control field 281, a Y gradient control field 283, and a Z gradient control field 285. The "Jump Limit" field 277 in the preferred embodiment may specify, for example, a loop counter for controlling the number of times a particular cycle and/or slice section is executed. The clock time field 279 controls the duration of a particular state (e.g., so as to provide a different phase encoding value). X, Y and X gradient fields 281, 283, 285 may similarly electronically specify different phase encoding values. Microinstructions 275(1)-275(n) also have embedded within them various absolute and/or relative addresses (not shown) pointing to subroutine section 260 and/or to other microinstructions within main routine section 262.

Detailed Description Text (22):
Typically, there are a relatively large number of cycles (e.g., 256 or more) specified within a single NMR pulse sequence (the number of cycles in part determines the spatial resolution of the resulting image, and higher resolution images are generally more useful). In addition, it is common practice in MRI to repeat data acquisition for the same slice and phase encoding parameters and to provide data averaging in order to reduce noise. Thus, a typical MRI pulse sequence may involve executing particular cycle sections 269 (and/or particular slice sections 271) a plurality of times to permit data averaging or other noise reduction techniques.

Detailed Description Text (23):
Referring back to FIGS. 3A and 4, host processor 126 loads the micro-instructions into Page 0 sequentially in ascending address order in the preferred embodiment (with the subroutine segment of microcode being written into the bottom of the page)--with page indicator PI corresponding to the most significant bit (MSB) of the memory addresses applied by the host processor to the sequencer. See copending commonly-assigned application Ser. No. 07/571,258 filed; 23 Aug. 1990 entitled "Continually Loadable Microcode Store for MRI Control Sequencers" (Attorney Docket No. 89-108) now issued U.S. Pat. No. 5,144,242 for additional details regarding the mechanisms used in the preferred embodiment for loading sequencer 140.

Detailed Description Text (24):
As mentioned, in the preferred embodiment the last executable micro-instructions the host processor 126 loads into either page of sequencer WCS 150 are always either a branch, if CSR condition bit set, to the first executable micro-instruction within the other page, followed by a STOP micro-instruction; or a STOP micro-instruction. Thus, the conditional branch micro-instruction the host processor loads into WCS 150

Page 0 is a branch to an as yet uninitialized location within WCS Page 1 (and in general, such conditional branch page transfer micro-instructions will point initially to locations within the other page of WCS that do not contain proper target micro-instructions for the conditional branch at the time the page transfer micro-instruction is loaded). In the preferred embodiment, the host processor 126 is never allowed to write into the page of WCS 150 that is being read by sequencer 140. The assumption is made in the preferred embodiment that by the time the sequencer 140 executes the conditional branch micro-instruction, host processor 126 will have not only written the proper micro-instruction into the location that is the conditional branch micro-instruction target--but will actually have written the entirety of the other page of WCS 150. The host will also have set the sequencer CSR condition bit. Note that in the preferred embodiment, this page transfer conditional branch micro-instruction is typically the only page transfer micro-instruction stored within the page.

Detailed Description Text (25):
Once host processor 126 loads Page 0 of WCS 150, it toggles its page indicator PI to indicate Page 1 (FIG. 4, block 204) and then starts sequencer 140 (FIG. 4, block 208). Sequencer 140 begins executing micro-instructions from Page 0 of WCS 150, with WCS Page 1 still being empty at this point (see FIG. 3B).

Detailed Description Text (26):
Host processor 126 then determines whether there is further microcode to be executed by sequencer 140 that has not yet been loaded into WCS 150 this determination was also made before loading the last page of microcode--since if no more microcode is to be loaded, the last instruction in that page should be specified as a STOP instruction) (FIG. 4, decision block 210). If there is no more microcode, the host processor 126 is finished loading the sequencer 140 and can perform other functions and processes ("N" exit of decision block 210, FIG. 4). Typically, however, there will be additional microcode to load ("Y" exit of decision block 210, FIG. 4) and host processor 126 will proceed to link the next portion of microcode until a further page worth of microcode has been generated (FIG. 4, block 212).

Detailed Description Text (27):
Linking of this initial Page 1 is partially performed when linking Page 0 in the preferred embodiment by copying the subroutine section 260 and a single (e.g., the first) cycle section 269 from the Page 0 microcode (stored in the host's Page 0 memory buffer 232) into a Page 1 memory buffer 234 within host computer memory 127. By editing this copied subroutine data and replicating and editing the cycle section (as will be explained shortly) to alter addresses and slice-specific parameters a microcode template is created which allows linking to be completed very efficiently. An important observation regarding the regularity and redundancy of sequencer microcode is that, generally, all of the slice-dependent values for an entire MRI pulse sequence are contained within a single (e.g., the first) cycle section 269; and substantially the only differences from one cycle section to another involve different phase encoding values (and also different addresses reflecting different sequencer memory addresses in which the different cycle sections are stored). Thus, it is possible to generate any phase encoding cycle section 269 by simply deriving or replicating it from any other phase encoding cycle section (and by providing appropriate addresses and cycle-specific values within the replicated code). Linking is completed by simply editing the microcode template in memory buffer 234 to replace certain cycle-specific values.

Detailed Description Text (28):
In this way, host processor 126 in accordance with the preferred embodiment is capable of relatively rapidly generating microcode contents for its Page 1 memory buffer 234 for loading into sequencer writable control store Page 1. Since WCS 150 Page 1 is empty at this point and sequencer 140 is reading Page 0, host processor 126 immediately begins loading this generated linked microcode from the Page 1 memory buffer 234 into sequencer WCS Page 1 using DMA techniques (FIG. 4, block 214).

Detailed Description Text (29):
FIG. 3C depicts schematically the situation existing at this point in time--with sequencer 140 reading micro-instructions from Page 0 of this sequencer control store and host processor 126 writing micro-instructions to Page 1 of the sequencer control store. Sequencer 140 in the preferred embodiment time multiplexes access to WCS 150 so that the sequencer and host processor 126 never simultaneously access the WCS (and thus, common memory addressing and other circuitry can be used for both

sequencer and host processor memory accesses). Even though sequencer 140 is perhaps two orders of magnitude faster than host processor 126, the time durations of normal NMR output states all but guarantee that host processor 126 will finish writing WCS 150 Page 1 before sequencer 140 finishes reading from WCS Page 0.

Detailed Description Text (30):
After host processor 126 finishes loading WCS Page 1, it toggles the page indicator (PI) to point to WSC Page 0 (block 214, FIG. 4) and then determines if there is still more microcode to load (decision block 210, FIG. 4). If there is, host processor 126 determines if the sequencer 140 is running in Page 0 (decision block 211, FIG. 4). If it is not, the next page of microcode is linked (block 212, FIG. 4) and loaded (block 214, FIG. 4)) (of if desired, linking and loading can be carried out simultaneously at block 214). Host processor 126 links this (and all subsequent) pages of microcode extremely efficiently by simply editing the contents of its memory buffers 232, 234 to replace certain parameters (e.g., cycle-specific values) with new values in order to produce linked microcode for reloading pages of the sequencer writable control store 150.

Detailed Description Text (31):
More particularly, the preferred embodiment uses a memory image of microcode previously loaded into a physical page of the sequencer 140 control store 150 as a "template" for generating microcode to be used to reload that sequencer control store physical page. Since the reloaded microcode occupies the same physical address space within the sequencer control store 150 as the previously loaded microcode (and due to the high degree of redundancy and similarity between the microcode to be reloaded and the subsequently loaded microcode), the same memory image used to provide the earlier loaded microcode can (with only minor editing) be used to reload the sequencer control store page.

Detailed Description Text (32):
In accordance with an important feature of one aspect of the present invention, only particular fields (e.g., fields 277, 279, 281, 283 and 285 as shown in FIG. 5B specifying jump limits, clock times, and X, Y and Z gradients) need to be edited from one page of microcode to the next.

Detailed Description Text (33):
By making all pages of microcode conform to the same structure and layout shown in FIG. 5, the preferred embodiment of the present invention dramatically simplifies the tasks involved in linking/generating subsequent pages of microcode. For example, assume the microcode initially loaded into Page 0 of sequencer writable control store 150 includes a particular subroutine section 260 and cycle sections 269(1)-269(J). It is possible to require every subsequent Page 0 of microcode to conform to precisely the same memory "template" or structure--and to include exactly the same subroutine section 260 and the same number (and placement in terms of memory addresses) of cycle sections 269 in such subsequent pages. In fact, it is possible to provide a one-to-one correspondence (on an instruction level) between an initial page memory image and subsequent page memory images--with corresponding instructions occupying corresponding memory addresses.

Detailed Description Text (35):
In accordance with an important aspect of one feature of the present invention, the various conditions expressed above are met so that only phase encoding related parameters (which vary from one cycle to the next) need to be changed from one microcode page to the next. The preferred embodiment Linker provided by the present invention takes advantage of the high degree of resulting regularity in microcode images from one page to the next by avoiding the time-intensive processing of slavishly regenerating subsequent pages of microcode once an initial page of microcode has been generated. More particularly, the preferred embodiment Linker transforms a memory image of microcode that has previously been loaded into, for example, Page 0 of the sequencer writable control store 150 into a memory image to be used to reload sequencer WCS 150 Page 0 by merely selectively replacing such phase encoding value fields 277-285 with new values appropriate for a different corresponding phase encoding cycle (such phase encoding values used for replacement may be obtained from Program Change Tables of the type described in Hoenninger '661).

Detailed Description Text (36):
In accordance with another important aspect of the present invention, memory images corresponding to each of plural physical pages of the sequencer control store 150

are generated and then continually reused. For example, the sequencer 140 shown in FIG. 2 provides a writable control store 150 having two physical pages: Page 0 and Page 1. In the preferred embodiment, host computer 126 maintains, in memory buffer 232, the image or template corresponding to sequencer 140 physical Page 0 created at FIG. 4 block 202 (and later changed, perhaps successive times, at FIG. 4 block 212); and also maintains in memory buffer 234 an image or template corresponding to sequencer 140 physical page 1.

Detailed Description Text (37):
Because, in the preferred embodiment, the sequencer physical pages have different memory addresses, the microcode to be loaded into those pages similarly must specify different absolute (and possibly also relative) addresses (e.g., for "jumps", branches, and loops). Although such addresses differ from one page to the other (i.e., from Page 0 to Page 1), the preferred embodiment Fast Linker provides that the addresses do not differ for microcode reloaded into the same physical sequencer page. By always maintaining a microcode memory image or template corresponding to each physical sequencer control store page, it is possible to reuse all of the previously generated address information by loading the appropriate memory image into the sequencer physical page to be reloaded. By reusing most of a previously generated sequencer microcode memory image (thus eliminating the need to calculate or generate new address information each time a sequencer control store 150 page needs to be reloaded, and even eliminating the need to replicate code), the preferred embodiment Fast Linker can run much faster and execute far fewer steps than what might be possible if a less complete (e.g., single cycle) template were to be used as the basis for generating the next page worth of microcode.

Detailed Description Text (38):
Host processor 126 does not attempt to access WCS 150 Page 0 until sequencer 140 indicates (e.g., by changing a status bit) that it has finished with Page 0 and is now reading from Page 1. Host processor 126 examines a sequencer status bit periodically and performs other functions, e.g., data acquisition and display with linking running as a non "time critical" process (block 213, FIG. 4) while waiting for sequencer 140 to finish executing the current page. Due to the extremely rapid and efficient nature of the linking process of block 218, host processor 126 will typically be finished editing the contents of Page 0 memory buffer 232 long before sequencer 140 has finished executing the microcode within its WCS Page 0.

Detailed Description Text (39):
When sequencer 140 reaches the end of the microcode routines loaded within WCS 150 Page 0, it executes the JUMP microinstruction 265 (mentioned earlier) to the first executable micro-instruction 263 stored within WCS Page 1. When the host reads the sequencer command and status register (CSR) and the CSR indicates that the sequencer has moved on to WCS 150 Page 1 (as tested for by decision block 211, FIG. 4), host processor 126 links and loads microcode from its Page 0 memory buffer 232 into WCS 150 Page 0 (FIG. 4, block 214). This situation is depicted in FIG. 3D--which shows host processor 126 writing to WCS 150 Page 0 while sequencer 140 reads from WCS Page 1.

Detailed Description Text (40):
Once host processor 126 finishes writing to Page 0, it toggles PI again (FIG. 4 block 214), determines if there is more microcode to load (FIG. 4 decision block 210) and repeats blocks 211, 212, 213 and 214 (i.e., by simply repetitively editing the contents of memory buffers 232, 234 in place as many times as necessary, each time replacing all cycle-specific values with new values) until there is no more microcode to link and load. The sequence of WCS 150 events thus alternate between FIG. 3C and FIG. 3D as many times as is necessary to load and run all of the microcode for the selected NMR sequence.

Detailed Description Text (41):
When host processor 126 finally determines in block 212 that there is no more microcode to link, it overwrites the next microinstruction in the memory buffer 232, 234 it is currently editing with a STOP instruction. When host processor 126 loads the contents of this memory buffer into sequencer writable control store 150, the host processor only loads the buffer up to the STOP instruction and then stops loading. This STOP instruction in the preferred embodiment acts as a halt instruction to the sequencer 140.

Detailed Description Text (42):
Because host processor 126 and sequencer 140 provide for continual linking and

loading of WCS 150 while sequencer 140 is running, the user/programmer may view WCS 150 as an ideal virtual control store having an unlimited size. Programmers may write NMR microcode sequences without concern for whether they will "fit" into the physical memory space provided by WCS 150. Reloading of WCS 150 is completely transparent to ongoing NMR pulse sequences and causes no troublesome interruption of such sequences, and microcode is linked and loaded "on the fly" using a multitasking processor used simultaneously for data acquisition, reconstruction and display functions without placing undue demands on the processor's resources (and without increasing the time between user input of a "link and load" command and the time the sequencer 140 starts running).

Detailed Description Text (43):
III. More Detailed Description of Fast Linker Exemplary Program Control Steps

Detailed Description Text (44):
Referring first briefly to FIG. 4, it can be seen that two different "link microcode" blocks are shown: "link Page 0 of microcode" block 202 and "link next page of microcode" block 212. In the preferred embodiment, block 202 links the initial Page 0 of microcode and creates the Page 1 microcode template and block 212 links all subsequent pages of microcode. Great efficiency and speed advantages are provided by the present invention chiefly through reuse by block 212 of the microcode provided by block 202--although the same basic "editing in place" steps are performed in the preferred embodiment for "link and load" steps 202 and 212. Additional details concerning exemplary program control steps and data structures provided in the preferred embodiment Fast Linker in accordance with the present invention will now be discussed in conjunction with FIGS. 6A-6F and 7A-7C.

Detailed Description Text (45):
Referring now to FIG. 6A, "start" block 1500 is called by host processor 126 in the preferred embodiment to execute the Linker object (hereafter "Fast Linker") of a program called MRIMON (a detached control program hosted under the VMS operating system). The MRIMON program controls all hardware needed to generate data for acquisition and processing by the host processor 126. MRIMON communicates as a server with client processes on host processor 126 through VMS mailboxes to perform system control functions (such functions in the preferred embodiment including setting system hardware parameters, maintaining control sequence data bases, linking microcode from the system control database and loading it into the sequencer 140 for execution, loading waveforms for RF modulation into a digital random waveform generator, and performing runtime diagnostics on the hardware).

Detailed Description Text (46):
The Fast Linker provided by the preferred embodiment begins by parsing a user-inputted link command ("Link Control Statement") to make the link table for the subroutines and the main routines and to determine the r index range (block 1502). The Fast Linker further parses the linker command to make the slice index table and to determine the s index range, s position and s index hop size (block 1504). The Fast Linker then parses the linker command to make the cycle index table (block 1506), and to make the level table (including an alternate level if one is specified, block 1508). The Fast Linker also makes the symbol table for the subroutines and the main routines, and determines the subroutine maximum microcode address (block 1510). The Fast Linker then begins executing an outer link command loop (which in the preferred embodiment includes support for "alternate levels", e.g., to permit collection of data for tracking the magnetic field so as to correct for magnetic field inhomogeneities) at block 1512.

Detailed Description Text (47):
Within this outer link command loop, the Fast Linker first initializes a pointer (called "pcttbl") to a PCT table data structure used to store (a) PCT identifications, and (b) offsets to instructions and to fields within an instruction for a cycle of main routines in the microcode template (block 1512). FIG. 7A is a graphical illustration of an exemplary format for such a PCT table data structure 1600. This table includes multiple entries 1602(1)-1602(n), each entry including an "offset" record 1604 (specifying an offset from a particular microinstruction to be edited from the beginning of the cycle section 269); a "nument" record 1606 (which specifies the number of entries in an associated PCT); a "pctfld" record 1608 (specifying a type of PCT entry); and a "tag" record 1610 (this tag record points to a particular program change table generated by the microcode assembler from which a cycle-specific and/or slice-specific value is to be obtained). This PCTTBL data structure 1600 thus provides a linkage between (a) each multi-entry and

cycle-specific value within each of the PCTs and (b) individual instruction fields within the memory image templates contained within memory buffers 232, 234. Moreover, in the preferred embodiment there is an entry 1602 within PCTTBL data structure 1600 corresponding to each microinstruction field within a (every) cycle section 269 that is to receive a multi-entry PCT value. Because the templates within the Page 0 and Page 1 memory buffers 232, 234 are essential identical (except for embedded addresses) to one another in the preferred embodiment, a single PCTTBL data structure 1600 can be used for both templates in the preferred embodiment.

Detailed Description Text (48):
Next, the preferred embodiment Fast Linker links the Page 0 subroutines in the Page 0 load buffer 232 using all tables and constants determined in steps 1502-1512 (block 1514). In the preferred embodiment, the subroutines are loaded first at microcode address 0, with the first subroutine always being PSEG1. The Fast Linker similarly links the Page 0 main routines in the Page 0 load buffer for a single cycle (i.e., one memory image of the main routines for one cycle index value to be determined later), this cycle data being loaded for the specified set of cycles at the appropriate levels. (In the preferred embodiment, a single Link Control Statement can specify the equivalent of separate link commands for alternate and primary levels, with the alternate levels occurring once at the beginning and once at the end of the primary level, e.g., to conveniently permit magnetic field tracking). The Fast Linker also creates the PCT table data structure 1600 shown in FIG. 7A at this time (block 1516). Note that the single entry PCTs are also accessed and values inserted into the correct instruction and microcode fields at this time--leaving only fields associated with multi-entry PCTs (e.g., values and parameters which depend on phase encoding selection) to be inserted later.

Detailed Description Text (49):
The preferred embodiment fast linker then initializes a pointer to an address table pointed to by a pointer called "attbl" (block 1518). This address table is used to store the offsets of microcode instructions within a cycle which require address updating when the image of the cycle microcode is copied to a new absolute memory location (and is used to build the PCTTBL data structure 1600). In addition, page template control block data structures 1650 (one for each of Page 0 memory buffer 232 and Page 1 memory buffer 234, see FIG. 7B) are set up to keep track of microcode base addresses (record 1654), number of (and which) cycles the buffer contains (records 1656, 1658, 1666), and DMA status (records 1660, 1662, 1664).

Detailed Description Text (50):
The memory image of the initial Page 0 of microcode within Page 0 memory buffer 232 is then completed by copying (replicating) the first cycle in Page 0 repetitively and updating addresses in instructions as appropriate for execution at a new absolute address (block 1520). At this point in time, the Page 0 memory buffer 232 still does not contain loadable microcode in the preferred embodiment--since multi-entry PCT values have yet to be inserted. Rather, the Page 0 memory buffer 232 contains a "template" that can be efficiently linked through editing to provide loadable microcode--as will be described shortly.

Detailed Description Text (51):
If the number and size of the main routines in the sequence require further microcode to be generated, the Page 1 memory buffer 234 is also loaded with microcode. To create a microcode memory image within Page 1 memory buffer 234, the subroutine section 260 and a single cycle section (e.g., 269(1)) of microcode are copied from the Page 0 memory buffer 232 into the Page 1 memory buffer. (block 1522). All absolute addresses specified within the Page 1 memory buffer 234 are adjusted during-this copying process to conform with the different physical location of Page 1 within sequencer writable control store 150. In the preferred embodiment, Page 1 begins at WCS 150 absolute address (location) 16384 instead of address (location) 0--and the absolute addresses within Page 1 memory buffer 234 are adjusted accordingly (block 1522). The Page 1 memory buffer 234 is then enumerated by replicating the single cycle, inserting new addresses and single-entry PCT values as before to complete the microcode template.

Detailed Description Text (52):
If the sequencer 140 is currently running (i.e., if it is executing microcode produced as the result of an earlier link and load command), the host processor 126 waits for the sequencer to finish (e.g., by periodically checking a control status register within the sequencer to determine when the sequencer finishes and/or resetting the sequencer if a hardware error is detected). When the sequencer has

(is) stopped, the preferred embodiment Fast Linker if necessary (e.g., due to the use of alternate levels) sets the system receive gain to the correct gain for the current link command level (block 1524). The Fast Linker then efficiently and rapidly links the Page 0 template stored in Page 0 memory buffer 232 to produce an initial "Page 0" of microcode and loads the linked microcode from the memory buffer 232 into Page 0 of sequencer writable control store 150 using DMA transfers (block 1526).

Detailed Description Text (53):
To perform the "link and load" task of block 1526, host processor 126 calls a function named "lk.sub.-- tmplt()". This function "lk.sub.-- tmplt" links the Page 0 microcode template stored in memory buffer 232 (by editing the memory image template contained within the memory buffer to insert phase encoding and multi-entry PCT values from the program change tables created by blocks 1504-1508 using the PCTTBL data structure 1600 shown in FIG. 7A). This same function is also responsible for actually loading the microcode from the host memory buffer into the sequencer WCS 150. A more detailed schematic flowchart of this "lk-tmplt" function is set forth in FIG. 6D-6F.

Detailed Description Text (66):
Referring now to FIG. 6D, the preferred embodiment Fast Linker first checks to make sure sequencer 140 is not executing microinstructions from the current page (block 1702); if the sequencer is running out of the current page, the function returns with an error code (block 1704). Assuming this error condition does not arise, the Fast Linker accesses the page template data structure 1650 to get the base address in the current memory buffer (232, 234) for the first cycle (block 1706). Variables and pointers within the page template data structure 1650 (e.g., a DMA pointer) are initialized at this time, and an instruction array pointer is initialized in response to the memory buffer pointer record 1652 of the page template data structure 1650 (block 1708). A further, working instruction pointer ("wc.sub.-- iptr") is initialized in response to the instruction array pointer and the first cycle base address (block 1710). This working pointer is used to address microinstructions of the current cycle within the current page memory buffer (232, 234). Microcode parameters are then set up beforehand for loading cycle dependent microcode fields (block 1712). To complete initialization tasks, the beginning cycle is stored in record 1656 of the page template data structure 1650 (block 1714), and a "current tag" and "current cycle" counter are each initialized to 0 (block 1716).

Detailed Description Text (67):
At this point, the Fast Linker is ready to insert multi-entry PCT values into the instructions and fields listed in PCTTBL 1600 for all cycles in the cycle table or until the memory buffer (232, 234) has been completely edited. In the preferred embodiment, two separate DMAs (one for each half page) are used to provide concurrent linking and DMA loading of the sequencer 140.

Detailed Description Text (68):
The Fast Linker (at block 1718) divides the memory buffer into two half pages and selects the first half page (block 1718). The preferred embodiment Fast Linker then determines which cycle to do next (taking spin conditioning into account) by getting a "next" value from a formatted cycle table (i.e., a C value stored by block 1506) (block 1720). The Fast Linker determines if the end of the table has been reached, and branches to block 1755 if there are no more cycles to be done (block 1721). To actually update the multi-entry PCT values, the Fast Linker determines by referring to the PCTTBL data structure 1600 if (and where) the PCT value should be inserted. The Fast Linker first initializes a working pointer to point to the first entry of the PCTTBL data structure 1600 (block 1722). Assuming the end of the PCTTBL data structure 1600 has not been reached (decision block 1724), the Fast Linker gets the PCT value using data from the PCTTBL entry. Thus, in the preferred embodiment, the PCTTBL TAG record 1610 provides a linkage to a particular program change table; and as will be explained shortly, the PCT Field record 1608 provides a linkage to a specific microinstruction field to be written over-with the retrieved PCT value.

Detailed Description Text (69):
The retrieved PCT value is copied into a working variable (reformatting it in the process to provide for uniform insertion regardless of the length of the value retrieved from the PCT by block 1728), and the current tag and current cycle values are updated (block 1730).

Detailed Description Text (70):

The "PCT Field" record 1608 within the current PCTTBL entry 1602 is then tested to determine what type of microinstruction field is to be edited. In the preferred embodiment, the "lk.sub.-- tmplt" function edits five different types of fields:

Detailed Description Text (73):
X Gradient fields;

Detailed Description Text (74):
Y Gradient fields; and

Detailed Description Text (75):
Z Gradient fields.

Detailed Description Text (76):
The PCT field record 1608 indicates to the "lk.sub.-- tmplt" function which of these microinstruction fields are to be edited. Decision blocks 1732, 1736, 1740, 1744 and 1748 test this PCT field record 1608, and blocks 1734, 1738, 1742, 1746 and 1750 insert the retrieved PCT value into the appropriate position within an appropriate microinstruction within the current cycle. Such insertion is performed in the preferred embodiment by indexing into the memory buffer (232, 234). Such an insertion address is obtained in the preferred embodiment by using the contents of the Offset record 1604 within the current PCTTBL entry 1602 (this Offset value indicating the offset from the beginning of the cycle to the beginning of the microinstruction to be edited) to index from the beginning of the current cycle (contained in the working pointer wc.sub.-- iptr set up by block 1710); and by indexing with a further offset from the beginning of the microinstruction to the beginning of the microinstruction field to be replaced (this further offset depends upon whether the field to be edited is a Jump Limit, Clock, XGrad, YGrad or ZGrad field). The resulting pointer points to the beginning of a particular microinstruction field of a specific microinstruction within the memory buffer (232, 234) to be edited. The Fast Linker overwrites this microinstruction field with the obtained, formatted PCT value (since different microinstruction fields have different lengths, the number of bits to be overwritten also depends on whether the field to be edited is a Jump Limit, Clock, XGrad, YGrad or ZGrad field). The use of stored offsets for indexing into the microcode buffers (232, 234) provides high speed editing of the micro-instructions.

Detailed Description Text (77):
After the PCT value has been inserted as described above, the pointer initialized by block 1722 is updated to the next entry of the PCTTBL data structure 1600, and blocks 1724-1752 are repeated until the last entry of the PCTTBL data structure has been encountered (decision block 1724). Thus, the PCTTBL data structure 1600 may include multiple entries 1602 for the same PCT value--causing this same value to be inserted into multiple microinstructions within a given cycle section 269.

Detailed Description Text (79):
If the current half-page is not yet done being edited (decision block 1756), blocks 1720-1760 are repeated to inset all appropriate PCT values into all appropriate micro-instruction fields within the next cycle. If the current half-page is done being edited, the Fast Linker determines whether the second half-page has been linked but linking is still not complete (decision block 1758). If this is the case, the instruction pointer wc.sub.-- iptr is updated to include the conditional branch instruction 265 and STOP instruction 266 (see FIG. 5A) at the end of the microcode template. The page template data structure 1650 is then updated with the ending cycle (block 1760). The Fast Linker determines whether linking is completed (decision block 1761) and if so overwrites a STOP instruction at the beginning of the next cycle, updating pointer wc.sub.-- iptr in the process (block 1762). The Fast Linker then starts the DMA of the current half-page into sequencer WCS 150 after using pointer wc.sub.-- iptr to compute the transfer count (block 1764). This DMA process can occur while the Fast Linker is busy editing the other half-page since the VMS operating system is provided with a memory buffer pointer and transfer count and performs the DMA in parallel with other computer operations.

Detailed Description Text (80):
Meanwhile, the Fast Linker determines whether it has another half-page of microcode to edit (decision block 1766). If there is no more microcode in the memory buffer to edit (either because both half-pages have already been edited, or because linking has been completed, the function "lk.sub.-- tmplt" returns to the calling process (block 1770). Otherwise, the Fast Linker continues with the other half-page and

repeats blocks 1720-1766 so as to link and load that half-page.

Detailed Description Text (81):
Referring once again to FIG. 6B, once the initial Page 0 has been linked and loaded (block 1526), the Fast Linker updates the page state in data structures 1650, 1670 (block 1528), and sends a READY message to the client process executing on host processor 126 (block 1530). Upon receiving a responsive GO message from the client process (block 1530), the Fast Linker starts the sequencer executing Page 0 of WCS 150 (block 1532). The Fast Linker then enters the "link and load" loop (blocks 1534-1548)--where it remains until sequencer 140 finishes executing the microcode specified by the last Link and load command. Sequencer 140 is continually executing during the time the Fast Linker repetitively executes the "link and load" loop shown on FIG. 6C, and this loop has the effect of continually linking microcode for and continually loading this linked microcode into the sequencer writable control store 150.

Detailed Description Text (82):
At block 1534, the Fast Linker waits until the sequencer is not executing the page of WCS 150 that is next to be loaded (the first time through this "link and load" loop, the sequencer 140 will be executing Page 0 and the next page to be loaded will be Page 1, so this test will pass without any waiting). The Fast Linker then writes to the sequencer 140 Control Status Register to specify the next page to be written (block 1536), and links and loads that page (block 1538) using the page template contained within the appropriate memory buffer (232, 234). As will be understood, block 1538 is performed by calling the function "lk.sub.-- tmplt" described above in connection with FIGS. 6D-6F and block 1526. The Fast Linker then waits for the DMA process begun by block 1764 to complete (block 1540), and gates the sequencer 140 to allow execution to proceed from the current page to the page just loaded (block 1542). This gating is accomplished by writing a bit to the sequencer 140 Control Status Register, this bit being used to gate the conditional branch instruction at the end of the current page being executed (see FIG. 5, microinstructions 265, 266)--although under normal operating conditions within a given pulse sequence in the preferred embodiment, the sequencer 140 never actually waits on this gating even but instead branches to the next page with substantially no interruption. The Fast Linker then again updates the page template data structure 1650 and the sequencer state data structure 1670 (block 1544) and changes the page number to be loaded (block 1546).

Detailed Description Text (83):
The Fast Linker then tests (e.g., based on parameters passed to it by the "lk.sub.-- tmplt" function) whether there is more microcode to link and load (decision block 1548). The loop of blocks 1534-1548 is continually executed until there is no more microcode to link and load (i.e., until all of the microcode requested by the last Linker Control Statement has been generated and provided to sequencer 140). If there are additional Link commands to execute (e.g., to provide alternate "levels" of microcode; decision block 1550), then control returns to block 1512 so as to link and load additional microcode in response to such additional link commands. Otherwise, the Fast Linker simply waits for the sequencer 140 to finish executing the pulse sequence (or for the client process to send a reset message; block 1552), and then resets sequencer 1554 and sends a DONE message to the client process (block 1556) before returning to the calling process (block 1558).

Detailed Description Text (85):
Copending, commonly-assigned application Ser. No. 07/571,258 of Zeilenga et al filed 23 Aug. 1990 entitled "CONTINUALLY LOADABLE MICROCODE STORE FOR MRI CONTROL SEQUENCERS" (Attorney Docket No 89-108), now issued U.S. Pat. No. 5,144,242 (hereby expressly incorporated by reference herein) describes in great detail the structure and operation of an exemplary continually loadable microcode sequencer of the type suitable for use in conjunction with the Fast Linker provided by the present invention. For sake of completeness, a brief description of this suitable control sequencer is set forth below (the reader is referred to that copending Zeilenga et al application for a more complete description).

Detailed Description Text (86):
FIG. 8 is a high level block diagram of the architecture of the sequencer 140 shown in FIG. 2 of the type suitable for use with the preferred Linker provided by the present invention. This FIG. 8 design is based on a conventional pipelined bit-slice CPU architecture but includes some significant enhancements which optimize the architecture for NMR pulse sequencing (and also provides continual loading of the

writable control store 150).

Detailed Description Text (87):
Sequencer 140 shown in FIG. 8 (which may be characterized as a state machine) includes a writable control store ("WCS") 150, a pipeline register (154,157,158), a control section 156, a system control multiplexer 157, and a programmable rate clock 160.

Detailed Description Text (88):
Control store 150 in the preferred embodiment includes a random access memory (RAM) the contents of which can be continually loaded by host processor 126 so as to contain a desired microprogram.

Detailed Description Text (89):
Exemplary micro-instructions each occupy the entire width of the WCS 150 at a corresponding address. The micro-instructions (an exemplary abbreviated format for which is shown at 152) each include an instruction field 152a, a clock time field 152b, and a system control field 152c and a WAIT field 152d.

Detailed Description Text (90):
The micro-instruction field 152a preferably contains an operational code or equivalent that controls state branching by the sequencer. For example, micro-instruction field 152a may contain a branch "op code" (e.g., "continue," unconditional jump, or conditional jump) and associated relative or absolute address information specifying a branch address of WCS 150 to branch to.

Detailed Description Text (91):
This micro-instruction field 152a is latched by pipeline register 154, which is composed of an input latch and output register. Pipeline register 154, 157 and 158 hold the current sequencer state N. The next state is addressed by the control section 156 as soon as possible after the state transition to state N if the duration of N is 250 ns. State N+1 is present at the output of the writable control store 150 within 250 nsec. If state N has a duration of only 250 nsec, then the pipeline register is loaded with state N+1 immediately due to an output from programmable rate clock 160. If state N lasts longer than 250 nsec., then the pipeline output register is not loaded immediately.

Detailed Description Text (92):
At the end of a state (N) in the preferred embodiment sequencer 140, a state change is initiated to cause the new current (N+1th) instruction field 152a to be stored within pipeline instruction register 154. The control section 156 then addresses a next (N+2) micro-instruction stored within WCS 150 immediately if the duration of the new current instruction is 250 ns. Control section 156 decodes the instruction contained within register 154 at the end of state N+1 and generates the address of a next (N+2) micro-instruction to be fetched. Control section 156 applies the address to WCS 150 to immediately fetch the next (N+2) micro-instruction. The next micro-instruction (N+2) is thus available at the output of WCS 150 and is latched by pipeline register 154 after the now-current state (N+1) ends.

Detailed Description Text (93):
The different fields 152a-d of the (N+1th) instruction are applied to different portions of the sequencer 140. For example, the system control field 152c is applied to system control multiplexer 157 so as to control various portions of the imaging system 116-122; the clock time field 152b is latched into programmable rate clock 160; and the WAIT field 152d is latched into control section 156.

Detailed Description Text (94):
The system control field 152c of micro-instruction format 152 contains control information for controlling various aspects of NMR system 100. System control multiplexer 157 selects, during periods of inactivity, NMR system default signals to prevent damage to the system and otherwise selects output signals provided by the current micro-instruction. The selected output signals are applied (via opto-isolators 162) to control various aspects of the NMR system (e.g., RF pulse ON/OFF state and RF frequency, the magnitudes of X, Y and Z magnetic field gradients, etc.).

Detailed Description Text (95):
In performing an NMR pulse sequence, speeds on the order of those needed in CPUs are almost never encountered. However, sequencer 140 must be capable of producing highly

repeatable and simultaneous sequences of a large number of multi-bit control fields at highly precise timings. The timing resolution is especially critical (e.g., a resolution of on the order of 250 ns is desirable) and timing must also be adjustable over a wide range (e.g., 250 ns to 8 seconds). In the design shown in FIG. 8, these timing requirements are met by storing in each instruction a 15-bit clock time (within field 152b) along with a single bit scaler select value. The contents of clock time field 152b are applied to control programmable rate clock block 160, which in turn provides timing signals to control the timing of control section 156 and other portions of sequencer 140. Programmable rate clock block 160 very precisely times a delay having a duration responsive to the contents of clock time field 152b, this time delay controlling the duration of the current state (corresponding to the current--that is, the Nth--instruction).

Detailed Description Text (96):
In order to permit the micro-instruction clock time field 152b to contain timing information associated with execution of the (current) instruction in which the field appears, it is necessary to load programmable clock block 160 and system control block 157 for the next instruction N+1 a short delay time after control section 156 generates micro-address N+1. Registers 154, 156 delay the instruction field 152a and the status information for the current (Nth) instruction until the programmable rate clock block 160 processes clock time field 152b for the current instruction. A delay block 164 introduces a suitable delay for loading programmable rate clock 160 with the contents of clock time field 152b to ensure that the programmable rate clock is loaded a short delay time after the next state micro-address (N+1) is generated by control section 156.

Detailed Description Text (97):
Micro-instruction sequences typically include micro-instructions of various different types. Most micro-instructions will have an instruction field corresponding to "CONTINUE," and will include a system control field 152c specifying the control states of the various portions of the NMR system (e.g., RF transmitter on/off, gradient magnet intensities, etc.) and a clock time field 152b specifying the duration of that sequencer state (i.e., how long the NMR system is to maintain the particular control settings specified by control field 152c). Some micro-instructions may specify a conditional or unconditional branch to another micro-instruction, and some may specify a WAIT (externally gated) state.

Detailed Description Text (98):
FIG. 9 is block diagram of the portions of an overall, exemplary preferred architecture of sequencer 140 shown in FIG. 5 relevant to loading and other access to the sequencer microcode writable control store (WCS) 150. Briefly, sequencer 140 as shown in FIG. 9 includes WCS 150, a host bus interface 300, a control section 400, programmable rate clock 160, a program counter 500, output latches 157, and a read status logic block 550. Various internal busses (including an internal multiplexed data/address bus DA, an internal control bus BCON, and a further internal bus BBUF) provide data, control and other signal paths between the various components of sequencer 140.

Detailed Description Text (99):
Sequencer 140 interfaces with the peripheral bus of host processor 126 via host bus interface 300. In the preferred embodiment, host processor 126 is a VAX general purpose digital computer manufactured by Digital Equipment Corporation (DEC), Maynard, Mass., and the host bus configuration and protocol correspond to the "Q22" QBUS standards promulgated by DEC. Host bus interface 300 provides an interface for this conventional Q bus, including an address/data interface 302 and a control signal interface 350. Host bus interface 300 communicates principally with sequencer control section 400, although it also has direct access to sequencer internal data/address bus DA.

Detailed Description Text (100):
The host processor 126 QBUS is a conventional 16-bit multiplexed data/address bus exhibiting a 10 .mu.s time-out, and communicates with its peripherals using standard DEC signalling protocol. As those skilled in the art well know, detailed information about the structure, operation and protocols of this QBUS may be found in standard publications of DEC. Briefly, host processor 126 writes to sequencer by asserting a write control signal along with a 16-bit address within the sequencer memory space; and then by asserting data to be written to the specified sequencer memory location. The host processor 126 will continue to assert the data until either: (a) the bus times out (10 .mu.s later), or (b) the sequencer asserts an acknowledgement signal

"BRPLY"--at which time the host bus cycle terminates. Sequencer 140 communicates with host processor 126 (and receives data for loading into WCS 150) via this QBUS using standard DEC protocol.

Detailed Description Text (101):
If the host attempts to write to WCS 150 at the same time that sequencer 140 needs to read from the WCS, the sequencer simply extends the host bus cycle (i.e., by waiting until the data has been written before asserting the acknowledgement signal). Thus, in the preferred embodiment there is no need to buffer much data from the QBUS; rather, each word of data from the QBUS is simply latched (by a single word latch in the preferred embodiment) and written directly into WCS 150 at a time selected by the sequencer control section 400. Sequencer 140, in the preferred embodiment, extends the host bus cycle until the write has actually been completed by delaying transmission of the acknowledge signal protocol required for the host bus cycle to complete.

Detailed Description Text (102):
Sequencer control section (SCS) 400 in the preferred embodiment provides synchronization and control signals for the remainder of sequencer 140. One of the blocks intimately coupled to SCS 400 is a 15-bit auto-increment program (location) counter 500 that applies addresses to WCS 150 specifying locations containing micro-instructions to be executed by sequencer 140 (with the most significant bit A14 of the program counter address selecting between pages of WCS 150 in the preferred embodiment). Program counter 500 is incremented (or, alternatively, loaded in parallel from the micro-instruction instruction field 152a) at a time determined by the output of programmable rate clock (i.e, indicating the end of the current state) so as to fetch the micro-instruction corresponding to a next state from WCS 150. As explained previously, a pipeline register (154,158 in FIG. 8, and shown in FIG. 9 as a latched output of RAM 600) is used to hold the "next state" micro-instruction.

Detailed Description Text (103):
Host processor 126 can read and write to WCS 150. When host processor 120 reads from sequencer 140 it may also read a 16-bit status word generated by read status logic block 550. The status word provided by read status logic block 550 includes such information as the current page of WCS (1 or 0) being accessed by the sequencer, various error condition signals (e.g., indicating that the host attempted to write to the same page of WCS 150 as the sequencer 140 was reading from), and parity error related signals.

Detailed Description Text (105):
Parity-related components 1100-1300 within WCS 150 ensure that no errors occur during reading from the WCS. Memory address multiplexer 1000 selects between access of WCS 150 by host processor 126 (via row counter 900 and column counter 700) and access of the WCS by sequencer 140 (via program counter 500).

Detailed Description Text (106):
Since the host processor QBUS data path is sixteen bits wide, the RAM 600 memory array must be accessed and written to in 16-bit wide portions when it is being loaded by host processor 126. Thus, for purposes of loading, RAM 600 is accessed two 8-bit RAM chips at a time (each "unit" of the memory thus comprises two RAM chips providing a 16-bit wide block)--and host processor 126 thus writes into a sequence of multiple (e.g., N) 16-bit wide "columns" of a row before moving on to the next row. For purposes of writing to RAM 600 from the host processor 126 QBUS, column counter 700 and associated memory chip select logic 800 generates a sequence of control signals /WE, /OE (in this specification, a negative logic signal is indicated by the symbol "/" preceding the signal name) in order to select "columns" of the RAM array--and row counter 900 provides an auto-increment row address count (auto-increment is in response to a "carry out" from column counter 700 in the preferred embodiment) for selection of an ascending address order sequence of rows of RAM 600.

Detailed Description Text (107):
To begin a write to sequencer 140, host processor 126 simply addresses the sequencer and then applies to the bus an appropriate number (e.g., 32K.times.N) 16-bit words (where N is the width of the sequencer micro-instruction divided by 16) in an appropriate order (as predetermined beforehand by the correspondence between the organization of columns of RAM 600 with the micro-instruction output fields 152). Sequencer 140 automatically writes the transmitted words into RAM 600 (e.g.,

beginning at the "top" of a page of RAM and proceeding toward the "bottom" of the page) such that a maximum of one page of RAM is filled. Writing to RAM 600 is not truly "continuous" in the sense of being "uninterrupted"--since sequencer 140 if it is running, may from time to time extend a QBUS write cycle for one or more 250 ns sequencer micro-instruction cycle times while the sequencer takes priority to access WCS 150.

Detailed Description Text (108):
Sequencer 140 assumes that host processor 126 will always send down up to one full page of data (if the entire page is not needed, the unused space may be buffered with data that will not, if accidentally executed, cause undesired sequencer output states to occur). The host 126 may send down in excess of one full page of data--but an error condition will arise if this occurs while the sequencer is running.

Other Reference Publication (3):
Conway et al, "Circuit for A Digital Pulse Programmer," 48 Rev. Sci. Instrum., No. 6, p. 656, (Jun. 1977).

Other Reference Publication (4):
Caron, "A New Programmable Timer Designed for Pulsed NMR," 31 Journal of Magnetic Resonance, p. 357 (1978).

Other Reference Publication (5):
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Other Reference Publication (6):
Dart, "Highly Flexible Pulse Programmer for NMR Applications," 51 Rev. Sci. Instrum., No. 2, p. 224, (Feb. 1980).

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Thomann et al, "Digital Pulse Programmer for An Electron-spin-resonance Computer-controlled Pulsed Spectrometer," 55 Rev. Sci. Instrum., No. 3, p. 389, (Mar. 1984).

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Jensen et al, "A Universal Pulse Programmer for NMR Imaging," Proceedings of the Third Annual SMRM, p. 379, (1984).

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Sidky et al, "State-machine Digital Pulse Generator," 59 Rev. Sci. Instrum., No. 5, p. 806, (May 1988).

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CLAIMS:

1. In a magnetic resonance imaging system of the type including a magnetic field generator, an RF field generator, an RF receiver, a data acquisition subsystem, and a control sequencer, said magnetic field generator and said RF field generator cooperating to stimulate nuclear magnetic resonance phenomena within an object to be imaged, said RF receiver receiving NMR signals produced by said nuclear magnetic resonance phenomena, said data acquisition subsystem acquiring digitized signals, said control sequencer controlling at least one of said magnetic field generator, said RF field generator and said data acquisition subsystem, said control sequencer having a control store for storing and accessing instructions for execution,

a method of efficiently and rapidly generating instructions for execution by said control sequencer,

said method comprising:

(a) generating a sequencer control store memory image including sequencer instructions, said instructions including first parameters that define a first projection;

(b) loading said sequencer control store memory image, including said first

projection parameters, into said sequencer control store;

(c) executing, with said sequencer, said sequencer control store memory image loaded into said sequencer control store by said loading step (b);

(d) controlling, with said sequencer, said magnetic field generator and/or said RF field generator in response to execution of said sequencer control store memory image by said executing step (c) so as to stimulate nuclear magnetic resonance phenomena within said object;

(e) acquiring, with said RF receiver and said data acquisition subsystem, first NMR signals emitted by said nuclear magnetic resonance phenomena stimulated by said controlling step (d);

(f) reusing said sequencer control store memory image by rapidly replacing said first projection parameters within said sequencer control store memory image with second projection parameters defining a second projection to create an altered sequence control store memory image, and loading said altered sequencer control store memory image, including said second projection parameters, into said sequencer control store;

(g) executing, with said control sequencer, said altered sequencer control store memory image loaded by said reusing step (f);

(h) controlling, with said sequencer, said magnetic field generator and/or said RF field generator in response to execution of said altered memory image by said executing step (g) so as to stimulate nuclear magnetic resonance phenomena within said object;

(i) acquiring, with said RF receiver and said data acquisition subsystem, second NMR signals emitted by said nuclear magnetic resonance phenomena stimulated by said controlling step (h); and

(j) generating an image of said object based at least in part on said first and second NMR signals acquired by said steps (e) and (i).

3. A method as in claim 1 wherein:

said loading step (b) includes the step of loading said memory image into an addressable memory space provided by said sequencer control store; and

said reusing step (f) includes the step of rewriting said control store with said altered memory image.

4. A method as in claim 1 wherein

said generating step (a) includes storing and maintaining said memory image in a host memory buffer; and

said reusing step (f) comprises the step of editing said memory image in place in said host memory buffer.

5. A method as in claim 1 wherein said generating step (a) comprises storing a linked microcode memory image in a buffer, and said loading step (b) comprises loading said stored linked microcode memory image from said buffer into said control sequencer control store.

6. A method as in claim 1 wherein:

said generating step (a) includes:

defining an outer loop index value, and

specifying, within said memory image, plural physical addresses in dependence on said outer loop index value, and

said reusing step (f) comprises keeping constant the physical addresses within said memory image that are dependent on said outer loop index value.

7. A method as in claim 1 wherein:

said generating step (a) includes providing, within said memory image, at least one jump address to another location within said memory image, and

said reusing step (f) includes offsetting said jump address.

8. A method as in claim 1 wherein:

said generating step (a) includes providing, within said memory image, at least one jump address to a subroutine, and

said reusing step (f) includes maintaining said jump address constant.

9. A method as in claim 1 wherein said generating step (a) includes:

providing a Linker command defining an outer loop index, and

resolving Linker command nested loop dependent PCT parameter references except for PCT and other command references dependent on the outer loop index of the Linker command.

10. A method as in claim 1 wherein:

said generating step (a) comprises defining a Linker outer loop, defining a microcode image for at least a first page of the sequencer control store memory corresponding to a first part of the Linker outer loop, and identifying and resolving outer loop dependent microcode fields, and

said reusing step (f) includes reusing said microcode image for at least a second page of the control sequencer control store corresponding to at least one successive part of the Linker outer loop, and altering at least some of said outer loop dependent microcode fields.

11. A method as in claim 1 wherein said generating step (a) includes creating an instruction block, creating at least one data structure locating instructions within said instruction block that contain references dependent on an outer loop index, and repetitively copying said instruction block to form said memory image, said copying step including using said data structure to resolve at least those references dependent on said outer loop index.

12. A method as in claim 11 wherein said generating step (a) further includes storing, within said data structure, at least one address offset locating said instructions from the beginning of the block.

13. A method as in claim 11 wherein said generating step (a) further includes storing, within said data structure, at least one microcode field and at least one corresponding reference to be resolved.

14. A method as in claim 1 wherein said generating step (a) includes:

(1) linking a first main outer loop dependent block of microcode, and

(2) subsequently to said step (1), creating a template of the memory image for a first page of said sequencer control store by copying said microcode block repetitively to provide contiguous blocks of higher memory while changing addresses for jump instructions which refer to other instructions within said contiguous blocks.

15. A method as in claim 14 wherein said generating step (a) further includes placing within said first page a jump instruction to a second page of said sequencer control store if more than one page of microcode is required.

16. A method as in claim 14 wherein said generating step (a) further includes placing a stop instruction within said first page if more than one page of microcode is not required.

17. A method as in claim 14 wherein said generating step (a) further includes:

(x) defining at least one subroutine as part of said memory image; and

(y) creating a further template of a further memory image for a second page of said sequencer control store by copying said subroutine and the first main loop dependent block from said template of the memory image for said first page to a second memory image template while changing addresses of said jump instructions to reflect at least one physical address of the second page of said sequencer control store, to provide a second main loop dependent block.

19. A method as in claim 17 wherein said creating step (y) further includes placing, within said second memory image template, a jump instruction to said first sequencer control store page if more than two pages of microcode are needed.

21. A method as in claim 1 wherein said generating step (a) comprises:

(1) creating a data structure containing entries referencing instructions that contain projection dependent values, and

(2) reading said data structure entries and successively resolving said projection dependent values by supplying said first projection parameters based at least in part on said data structure entries using at least one outer loop index value.

23. A method as in claim 1 wherein said generating step (a) comprises storing said memory image in a computer memory, and said loading step (b) comprises copying said image from said computer memory to said control store.

24. A magnetic resonance imaging system for generating an image of an object, said system including:

a magnetic field generator;

an RF field generator cooperating with said magnetic field generator to stimulate nuclear magnetic resonance phenomena within said object;

a data acquisition subsystem for acquiring digitized NMR signals;

a control sequencer for controlling at least one of said magnetic field generator, said RF field generator and said data acquisition subsystem, said control sequencer having a control store for storing and accessing instructions for execution by said sequencer;

a host computer including a computer memory, said host computer performing the following functions:

(a) generating a first block of sequencer instructions including first parameters that define a first projection,

(b) storing said first block of sequencer instructions within said computer memory,

(c) loading said first block of sequencer instructions, including said first projection parameters, into said sequencer control store,

(d) rapidly altering said first block of instructions stored within said computer memory by maintaining said first block but replacing said stored first projection parameters with second projection parameters defining a second projection, and

(e) loading said altered first block of sequencer instructions, including said second projection parameters, into said control sequencer control store;

said sequencer including a processor that executes said first block of sequencer instructions and said altered first block of sequencer instructions out of said sequencer control store, and controls said magnetic field generator and/or said RF field generator in response to said execution so as to stimulate nuclear magnetic resonance phenomena within said object, said stimulated phenomena generating NMR signals;

a receiver and said data acquisition subsystem cooperating to receive and acquire at least first NMR signals corresponding to said first projection and second NMR signals corresponding to said second projection; and

a display coupled to said data acquisition subsystem that generates an image of said object based on said acquired first and second NMR signals.

25. Apparatus as in claim 24 wherein said block of instructions specifies at least one sequencer control store physical address.

26. Apparatus as in claim 24 wherein said first parameters comprise MRI cycle and/or slice dependent values.

27. Apparatus as in claim 24 wherein said host computer includes means for (a) loading said block of instructions into said control sequencer control store, and (b) subsequently loading said altered block of instructions into said control sequencer control store.

28. Apparatus as in claim 24 wherein said host computer includes means for overwriting, with said altered block of instructions, said block of instructions loaded into said control sequencer control store.

29. A system as in claim 24 wherein said host computer includes:

means for defining an outer loop index value,

means for specifying, within said first block, plural physical addresses in dependence on said outer loop index value, and

means for keeping constant, during said rapidly altering operation, the physical addresses within said first block that are dependent on said outer loop index value.

30. A system as in claim 24 wherein said host computer includes:

means for providing, within said first block, at least one jump address to another location within said first block, and

means for offsetting said jump address during said rapidly altering operation.

31. A system as in claim 24 wherein said host computer includes:

means for providing, within said first block, at least one jump address to a subroutine, and

means for maintaining said jump address constant during said rapidly altering operation.

32. A system as in claim 24 wherein said host computer comprises:

means for providing a Linker command defining an outer loop index, and

means for resolving Linker command nested loop dependent PCT parameter references except for PCT and other command references dependent on the outer loop index of the Linker command.

33. A system as in claim 24 wherein said host computer comprises:

means for defining a Linker outer loop, defining with said first block a microcode image for at least a first page of the sequencer control store memory corresponding to a first part of the Linker outer loop, and identifying and resolving outer loop dependent microcode fields, and

means for reusing said microcode image for at least a second page of the control sequencer control store corresponding to at least one successive part of the Linker outer loop, and altering at least some of said outer loop dependent microcode fields.

34. A system as in claim 24 wherein said host computer includes means for creating at least one data structure locating instructions within said first instruction block that contain references dependent on an outer loop index, and means for repetitively copying said first instruction block to form a memory image, said

copying means including means for using said data structure to resolve at least those references dependent on said outer loop index.

35. A system as in claim 34 wherein said host computer further includes means for storing, within said data structure, at least one address offset locating said instructions from the beginning of the first instruction block.

36. A system as in claim 34 wherein said host computer further includes means for storing, within said data structure, a microcode field and at least one associated reference to be resolved.

37. A system as in claim 24 wherein said host computer includes:

means for linking a first main outer loop dependent block of microcode, and

means for creating a template of the memory image for a first page of said sequencer control store by copying said microcode block repetitively to provide contiguous blocks of higher memory while changing addresses for jump instructions which refer to other instructions within said contiguous blocks.

38. A system as in claim 37 wherein said template creating means includes means for placing within said first page a jump instruction to a second page of said sequencer control store if more than one page of microcode is required.

40. A system as in claim 37 wherein said host computer further includes:

means for defining at least one subroutine as part of said memory image; and

means for creating a further template of a further memory image for a second page of sequencer control store by copying said subroutine and the first main loop dependent block from a first memory image template to a second memory image template while changing addresses of all jump instructions to reflect at least one physical address of the second page of said sequencer control store, to provide a second main loop dependent block.

42. A system as in claim 40 wherein said creating means includes means for placing, within said second memory image template, a jump instruction to said first sequencer control store page if more than two pages are needed.

43. A system as in claim 40 wherein said creating means includes means for placing a stop instruction to said first sequencer control store page within said second memory image template if more than two pages are not needed.

44. A system as in claim 24 wherein said host computer comprises:

means for creating a data structure containing entries referencing instructions that contain projection dependent values, and

means for reading said data structure entries and successively resolving said projection dependent values by supplying said first projection parameters based at least in part on said data structure entries using at least one outer loop index value.

45. In a magnetic resonance imaging system for imaging an object, said system including:

(i) a magnetic field generator,

(ii) an RF field generator,

(iii) a data acquisition subsystem,

(iv) a digital sequencer coupled to said magnetic field generator, said RF field generator, and said data acquisition subsystem, said sequencer including a sequencer memory for storing instructions,

(v) an RF receiver,

(vi) a display device, and

(vii) a digital computing arrangement coupled to said sequencer, said digital computing arrangement including a buffer,

a method of efficiently generating and supplying instructions to said sequencer memory comprising the following steps:

(A) storing a set of sequencer instructions in said buffer;

(B) generating a first set of projection-specific parameters corresponding to a first plurality of slices of said object;

(C) writing said first set of projection-specific parameters into said buffer as parameters for at least some of said set of stored sequencer instructions;

(D) copying said stored sequencer instructions including said first set of slice-specific parameters from said buffer to said sequencer memory;

(E) executing said instructions including said first set of slice-specific parameters with said sequencer from said sequencer memory to control at least one of said magnetic field generator and said RF field generator;

(F) receiving NMR signals corresponding to said first plurality of slices of said object with said RF receiver and digitizing them with said data acquisition subsystem;

(G) generating a further set of slice-specific parameters corresponding to a further plurality of slices of said object;

(H) reusing said set of said stored sequencer instructions by: (h1) replacing said first set of stored projection specific values with said further set of projection specific values, and (h2) copying said set of sequencer instructions including said further set of projection specific parameters from said buffer to said sequencer memory;

(I) executing said instructions copied by said reusing step (H) including said further set of projection specific parameters from said sequencer memory with said sequencer to control at least one of said magnetic field generator and said RF field generator;

(J) receiving NMR signals corresponding to said further plurality of slices with said RF receiver and said data acquisition subsystem; and

(K) generating, on said display device, an image based on said received NMR signals.

46. A method as in claim 45 wherein:

said method further includes defining an outer loop index value, and specifying, within said stored sequencer instructions, plural physical addresses in dependence on said outer loop index value, and

wherein said reusing step (H) comprises keeping constant the physical addresses within said stored sequencer instructions that are dependent on said outer loop index value.

47. A method as in claim 45 wherein:

said storing step (A) includes storing, within said buffer, an instruction having at least one jump address to another instruction within said buffer and

said reusing step (H) includes offsetting said jump address.

48. A method as in claim 45 wherein:

said storing step (A) includes storing, within said buffer, an instruction having at least one jump address to a subroutine, and

said reusing step (H) includes maintaining said jump address constant.

50. A method as in claim 45 wherein:

said method further comprises defining a Linker outer loop, defining a microcode image for at least a first page of the sequencer control store memory corresponding to a first part of the Linker outer loop, said step (A) storing said image in said buffer, and identifying and resolving outer loop dependent microcode fields, and

said reusing step (H) includes reusing said microcode image stored in said buffer for at least a second page of the control sequencer control store corresponding to at least one successive part of the Linker outer loop, and altering at least some of said outer loop dependent microcode fields.

52. A method as in claim 51 further including storing, within said data structure, at least one address offset locating said instructions from the beginning of the block.

53. A method as in claim 51 further including storing within said data structure the microcode field and at least one reference to be resolved.

54. A method as in claim 45 further including:

(1) linking a first main outer loop dependent block of microcode, and

(2) subsequently to said step (1), creating a template of the memory image for a first page of said sequencer control store by copying said microcode block repetitively to provide contiguous blocks of higher memory while changing addresses for jump instructions which refer to other instructions within said contiguous blocks, wherein said storing step comprises storing said template in said buffer.

55. A method as in claim 54 further including placing within said first page a jump instruction to a second page of said sequencer control store if more than one page of microcode is required.

57. A method as in claim 54 further including:

(x) defining at least one subroutine as part of a memory image; and

(y) creating a further template of a further memory image for a second page of sequencer control store by copying said subroutine and the first main loop dependent block from a first memory image template to a second memory image template while changing addresses of all jump instructions to reflect at least one physical address of the second page of said sequencer control store, to provide a second main loop dependent block.

59. A method as in claim 57 wherein said creating step (y) further includes placing, within said second memory image template, a jump instruction to said first sequencer control store page if more than two pages are needed.

60. A method as in claim 57 wherein said creating step (y) further includes placing a stop instruction to said first sequencer control store page within said second memory image template if more than two pages are not needed.

61. A method as in claim 21 further including:

(1) creating a data structure containing entries referencing instructions that contain projection dependent values, and

(2) reading said data structure entries and successively resolving said projection dependent values by supplying said first projection parameters based at least in part on said data structure entries using at least one outer loop index value.

62. In a magnetic resonance imaging system including:

a magnetic field generator;

an RF field generator cooperating with said magnetic field generator to stimulate nuclear magnetic resonance phenomena within an object to be imaged;

a control sequencer for controlling in real time at least one of said magnetic field generator and said RF field generator, said control sequencer including a control store for storing and accessing instructions for execution by said sequencer;

an RF receiver for receiving NMR signals;

a data acquisition subsystem; and

a display that displays an image based at least in part on said received NMR signals,

a method of linking microcode for execution by said control sequencer, said method comprising:

(1) creating a data structure having elements locating, within a first sequencer instruction block, at least one value dependent on an outer loop index;

(2) creating a first sequencer control store memory image template by successively copying said first instruction block;

(3) accessing said data structure elements:

(4) rapidly locating and resolving outer loop index dependent values within said first template based at least in part on said accessed data structure elements;

(5) creating a second sequencer control store memory image template by successively copying said first instruction block;

(6) rapidly locating and resolving outer loop index dependent values within said second template based at least in part on said accessed data structure elements;

(7) loading said first and second control store memory images into said sequencer control store;

(8) executing said loaded first and second control store memory images with said sequencer;

(9) controlling said magnetic and RF field generators based on said executing step to generate fields stimulating NMR phenomena within said object to be imaged;

(10) receiving NMR signals with said RF receiver;

(11) digitizing said received NMR signals with said data acquisition subsystems; and

(12) generating at least one image on said display based on said digitized received NMR signals.

63. A magnetic resonance imaging method comprising:

(1) providing a data structure having elements locating, within a first instruction block, at least one value dependent on an outer loop index;

(2) creating a first sequencer control store memory image template by replicating said first instruction block;

(3) rapidly locating within said first template and resolving outer loop index dependent values based at least in part on said data structure elements;

(4) creating a second sequencer control store memory image template by replicating said first instruction block;

(5) rapidly locating within said second template and resolving outer loop index dependent values based at least in part on said data structure elements;

(6) loading said first and second templates into a sequencer control store;

(7) executing instructions within said loaded templates with a sequencer coupled to said control store;

(8) controlling, in real time, generation of a magnetic field based on said sequencer execution;

(9) controlling, in real time, generation of an RF field based on said sequencer execution;

(10) receiving NMR signals generated in response to said magnetic and RF fields;

(11) acquiring and digitizing said received NMR signals, and

(12) displaying an image based at least in part on said digitized acquired NMR signals.

64. Magnetic resonance imaging apparatus comprising:

a main memory;

a sequencer having a control store;

means coupled to said main memory for generating a first block of sequencer instructions and for storing said first block within said main memory;

data structure generating means coupled to said main memory for creating a data structure having elements locating, within said first instruction block, at least one value dependent on an outer loop index;

replicating means coupled to said main memory for creating first and second sequencer control store memory image templates by replicating and storing, in said main memory, said first instruction block;

linking means, coupled to said main memory and coupled to receive said data structure, for rapidly locating within said first and second templates and resolving outer loop index dependent values based at least in part on said data structure elements to produce first and second sequencer memory images;

loading means coupled to said linking means for loading said first and second sequencer memory images into said sequencer control store,

wherein said sequencer further includes:

executing means coupled to said control store for executing instructions within said first and second sequencer memory images loaded into said sequencer control store,

means coupled to said executing means for controlling generation of a magnetic field based on said sequencer execution, and

means coupled to said executing means for controlling generation of an RF field based on said sequencer execution,

wherein said apparatus further comprises:

an RF receiver that receives NMR signals generated in response to said magnetic and RF fields;

a data acquisition subsystem that digitizes and acquires said received NMR signals; and

a display coupled to said data acquisition subsystem for displaying an image based at least in part on said received digitized and acquired NMR signals.

Search Results - Record(s) 1 through 8 of 8 returned.

☐ 1. Document ID: US 20020115941 A1

L46: Entry 1 of 8 File: PGPB Aug 22, 2002

PGPUB-DOCUMENT-NUMBER: 20020115941
PGPUB-FILING-TYPE: new
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TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in interior body regions

PUBLICATION-DATE: August 22, 2002

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US-CL-CURRENT: 600/523; 600/374, 702/68, 707/102

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

☐ 2. Document ID: US 20010044585 A1

L46: Entry 2 of 8 File: PGPB Nov 22, 2001

PGPUB-DOCUMENT-NUMBER: 20010044585
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DOCUMENT-IDENTIFIER: US 20010044585 A1

TITLE: Interactive systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions

PUBLICATION-DATE: November 22, 2001

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US-CL-CURRENT: 600/509

☐ 3. Document ID: US 6389311 B1

L46: Entry 3 of 8 File: USPT May 14, 2002

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DOCUMENT-IDENTIFIER: US 6389311 B1

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in interior body regions

DATE-ISSUED: May 14, 2002

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US-CL-CURRENT: 600/523

☐ 4. Document ID: US 6289239 B1

L46: Entry 4 of 8 File: USPT Sep 11, 2001

US-PAT-NO: 6289239
DOCUMENT-IDENTIFIER: US 6289239 B1

TITLE: Interactive systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions

DATE-ISSUED: September 11, 2001

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US-CL-CURRENT: 600/523

☐ 5. Document ID: US 6192266 B1

L46: Entry 5 of 8 File: USPT Feb 20, 2001

US-PAT-NO: 6192266
DOCUMENT-IDENTIFIER: US 6192266 B1

TITLE: Systems and methods for controlling the use of diagnostic or therapeutic instruments in interior body regions using real and idealized images

DATE-ISSUED: February 20, 2001

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US-CL-CURRENT: 600/427; 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 6. Document ID: US 6115626 A

L46: Entry 6 of 8 File: USPT Sep 5, 2000

US-PAT-NO: 6115626
DOCUMENT-IDENTIFIER: US 6115626 A

TITLE: Systems and methods using annotated images for controlling the use of diagnostic or therapeutic instruments in instruments in interior body regions

DATE-ISSUED: September 5, 2000

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US-CL-CURRENT: 600/427; 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw Desc | Image

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☐ 7. Document ID: US 6106460 A

L46: Entry 7 of 8 File: USPT Aug 22, 2000

US-PAT-NO: 6106460
DOCUMENT-IDENTIFIER: US 6106460 A

TITLE: Interface for controlling the display of images of diagnostic or therapeutic instruments in interior body regions and related data

DATE-ISSUED: August 22, 2000

INVENTOR-INFORMATION:

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US-CL-CURRENT: 600/300

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

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☐ 8. Document ID: US 6014581 A

L46: Entry 8 of 8 File: USPT Jan 11, 2000

US-PAT-NO: 6014581
DOCUMENT-IDENTIFIER: US 6014581 A

TITLE: Interface for performing a diagnostic or therapeutic procedure on heart tissue with an electrode structure

DATE-ISSUED: January 11, 2000

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Dupree; Daniel A.	Saratoga	CA		
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US-CL-CURRENT: 600/523

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC | Draw. Desc | Image

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OSCILLATABLE.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	4649
OSCILLATABLES.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	1
OSCILLATABLE:.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	1
OSCILLATABLLY.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	5
OSCILLATABLY.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	2579
(L45 AND (OSCILLAT$5 OR SYNTHESIZ$4 OR GENERAT$4 OR PRODUC$6 OR ENVELOP$4 OR MODULAT$5 OR WAVEFORM$6 OR WAVE-FORM$6 OR SHAP$5)).USPT,PGPB,JPAB,EPAB,DWPI,TDBD.	8

There are more results than shown above. Click here to view the entire set.

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Previous Page Next Page